Professor Allen Thomson M.D. F.R.S.
with the author's Compliments

CHAMBERS'S
ELEMENTARY SCIENCE MANUALS.

W. K. Cooper
Owens Coll
1887.

ZOOLOGY

A DESCRIPTION OF TYPES OF ANIMAL STRUCTURE

BY

ANDREW WILSON, PH.D., &c.

LECTURER ON ZOOLOGY AND COMPARATIVE ANATOMY IN THE EDINBURGH MEDICAL SCHOOL; EXAMINER IN NATURAL HISTORY AND BOTANY, UNIVERSITY OF GLASGOW, ETC.

W. & R. CHAMBERS
LONDON AND EDINBURGH
1877

21733

20637022

Edinburgh:
Printed by W. and R. Chambers.

PREFACE.

THE present Manual is intended to serve as an introduction to the study of Comparative Anatomy and Physiology, and may be used by students preparing for the elementary stage of the zoological section of the Science and Art Examinations. It is based on the method adopted by the leading teachers of Zoological Science —namely, that of selecting a few of the leading types of animal life, as exemplified by common animals, and of initiating the student into the study of zoology, through the description of the structure and physiology of these typical forms. In this way alone, is it possible to give the beginner broad and comprehensive views of animal organisation, on which a sound knowledge of the modifications of animal structure may be afterwards built up.

The descriptions have in most cases been verified by the Author's observations; and he has not hesitated to introduce here and there considerations of a somewhat theoretical nature, but which bear more or less directly on the maxims and precepts of zoology. The examination of a zoophyte has thus afforded a text for a discussion on the 'individuality' of animals; whilst the nature of 'homologies' and the physiological differences between animals have been illustrated by the examination of the lobster's exoskeleton, and by the comparison of Amœba with higher forms, respectively.

It may lastly be remarked, that in no case can the study of living organisms be satisfactorily carried on without the continual and direct examination of the objects described. These lessons must therefore be regarded as constituting a guide-book to practical work in zoology, in which either teacher or student, provided with a microscope, and having access to a few common animals, may find simplified descriptions of the leading types of the zoologist's study. The Author would also hope that, incidentally, the use of the Manual may promote the extension of biological knowledge, which constitutes one of the most powerful sources of culture at the command of the modern educationist.

EDINBURGH, *April* 1877.

CONTENTS.

PAGE

CHAPTER I.—
ANIMAL LIFE IN ITS LOWER FORMS—AMŒBA....... 7

CHAPTER II.—
THE HYDRA, OR COMMON FRESH-WATER POLYPE...19

CHAPTER III.—
ZOOPHYTES, AND THEIR LIFE-HISTORY................32

CHAPTER IV.—
THE SEA-ANEMONE AND ITS LIFE-HISTORY...........42

CHAPTER V.—
THE FRESH-WATER MUSSEL................................56

CHAPTER VI.—
THE COMMON LOBSTER..85

CHAPTER VII.—
THE STRUCTURE, PHYSIOLOGY, AND DEVELOPMENT OF THE COMMON FROG......................109

QUESTIONS...145

CHAPTER I.

ANIMAL LIFE IN ITS LOWER FORMS—AMŒBA.

1. The objects that surround us in the world may be conveniently divided into two great groups or series, according as they are *living* objects or *lifeless* ones. To the living objects we apply the term *organic*, whilst the lifeless things are known as *inorganic* objects. The science which investigates the details of living or organic beings, and makes us familiar with every part of their history, is named *Biology* (Gr. *bios*, life; and *logos*, science). The inorganic objects of our world fall to be considered by such sciences as Geology, Chemistry, Natural Philosophy, and the like.

2. Living beings are themselves susceptible of division into two great groups. These groups we term familiarly *animals* and *plants*. Hence the science of Biology necessarily comprehends two divisions—*Zoology*, which investigates the life-history of animals; and *Botany*, dealing with

the details of plant-structure and life. It is well at the outset to remark, that although practically, and for the sake of convenience, we may make a distinction between animals and plants, and between the respective sciences which deal with them, no sharp line of separation can in reality be drawn. In some cases, it may be absolutely impossible to determine the exact nature of an organism, or to say whether it is an animal or plant; and thus the biologist must become acquainted with the structure and history of both groups of living beings, if he is to perfectly represent his science. Zoology and Botany, in fact, require to be studied together, in view of the intimate relations which exist between the animal and plant worlds.

THE AMŒBA AND ITS LIFE-HISTORY.

3. The subject of the present series of lessons is the animal creation. As an example of the manner in which all animals, high and low alike, must be studied, we shall select one of the lowest animal organisms, and endeavour to embody in its life-history the chief details which await the consideration of the zoologist. The *Amœba*, or 'Proteus-animalcule' (fig. 1) as it was formerly named, is one of

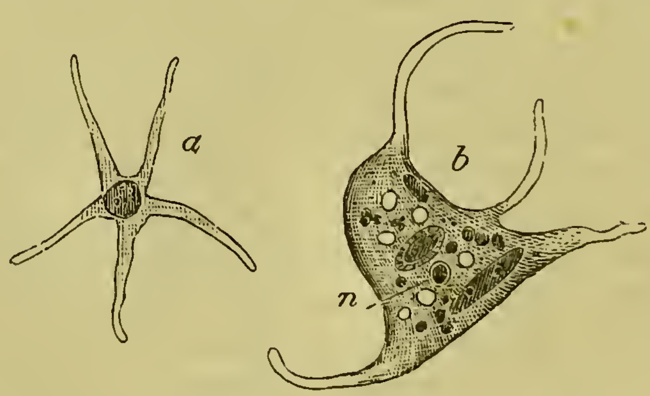

Fig. 1.—Amœba: *a*, young *Amœba radiosa*, with pseudopodia protruded; *b*, older specimen of *A. radiosa*, shewing nucleus, *n*, and food-vacuoles (both highly magnified).

the most familiar organisms with which the microscopist is acquainted. Various species of these animalcules are

found in fresh water which has lain stagnant for some time, in damp earth and mud, in infusions of organic matter, and also in the sea. They are all of minute or microscopic size, and may vary in diameter from the $\frac{1}{100}$th to the $\frac{1}{300}$th part of an inch. When one of these beings is watched by the aid of a microscope, the body is seen to consist of a speck of colourless jelly-like matter, to which the names *protoplasm*, *bioplasm*, and *sarcode* have been given. This protoplasm is a highly complex substance, and, as exemplified by the amœba, may of itself form an entire and complete animal; whilst many of the lowest plants are similarly composed of this matter in its simplest and most primitive condition.

4. **PROTOPLASM** is an albuminous substance, and one of a great class of compounds to which the name of *Protein* compounds has been applied. From its constant association with living beings, it has been named the 'physical basis of life.' The bodies of all living organisms are composed of this substance in their earliest state. In the higher animals, the protoplasm becomes developed or differentiated into many different tissues; whereas in lower organisms it retains much of, or all its primitive simplicity. The *life* or *vitality* of protoplasm is not certainly known to exist under any other circumstances than when derived from pre-existing and living protoplasm. Its chemical composition shews protoplasm to consist of carbon, hydrogen, nitrogen, and oxygen; and on physical examination, it is found to undergo *contraction* when stimulated by electricity; whilst, when subjected to a temperature of from 30° to 45° or 50° Centigrade (86°, 113°, 122° Fahr.), it coagulates or undergoes a process known as 'heat-stiffening.'

5. **Structure of Amœba.**—The body of the amœba (fig. 2, A) is seen to be of a firmer consistence towards its outer surface than internally. And whilst the name of *ectosarc*, *b*, has been given to the firmer and outer layer of the body, the term *endosarc*, *a*, is applied to the more fluid internal layer. The latter portion of its body may exhibit a granular appearance, produced by the presence of numerous minute solid particles in the general protoplasm. Within the ectosarc, and sometimes within the endosarc, one or more clear

spaces may be seen to exist, and these spaces exhibit motions of expansion (*diastole*) and contraction (*systole*). They are termed *contractile vesicles* (fig. 2, A, B, *c*), and are apparently permanent organs. These vesicles are not to

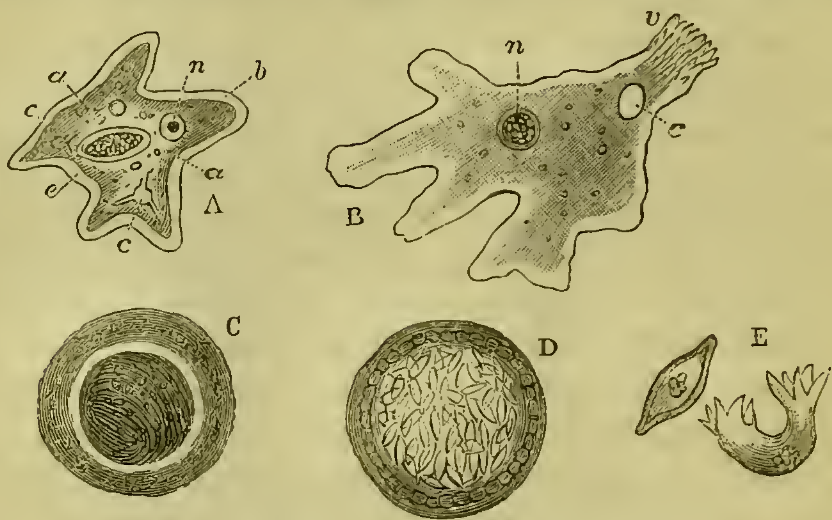

Fig. 2.—Morphology of Amœba: A, diagrammatic figure of Amœba; *a*, endosarc; *b*, ectosarc; *c*, *c*, contractile vesicles; *n*, nucleus. B, *Amœba princeps*; *c*, contractile vesicle; *n*, nucleus; *v*, so-called 'villous' region. C, Amœba encysted. D, further stage of C, shewing interior of cyst occupied by *pseudonavicellæ*. E, two pseudonavicellæ, or young Amœbæ liberated (all highly magnified).

be confused with certain other clear spaces of temporary nature, named *food-vacuoles*. The only remaining structure exhibited by the amœba is a solid particle situated in the endosarc, and named the *nucleus* or *endoplast* (fig. 2, A, B, *n*). This body may contain a smaller particle, named the *nucleolus;* and both structures are rather characteristic of many lower animals allied to the amœba, and included with it in the sub-kingdom *Protozoa*.

A living amœba is soon seen to merit its name of Proteus-animalcule, or, indeed, its ordinary designation (Gr. *amoibos*, changing), since it may be observed to be continually altering the shape and configuration of its body; passing or literally flowing from one shape into another, and moving about by pushing out its soft protoplasmic body into certain processes named *pseudopodia*. These processes, usually of blunt, finger-like nature, appear generally to be emitted from any part of the body; but in some cases they

have been described as being more limited in their origin. When the animalcule wishes to move or to seize particles of food, part of the body is pushed out into one or more pseudopodia. The ectosarc appears to be chiefly concerned in the formation of these processes; but the endosarc also seems to pass into the pseudopodia, which thus become prolongations of both layers of the body-protoplasm. It is the power of emitting pseudopodia which enables these animalcules to alter their shape, as already described; and this power, moreover, is a notable characteristic of the group (*Rhizopoda*) of organisms of which the amœba is a typical representative.

6. **Physiology of Amœba.**—When a particle of food approaches the amœba, it seizes the minute morsel by means of the pseudopodia. The particle enters the soft protoplasm of the body apparently by passing through the ectosarc, which latter, it may be presumed, readily admits solid matters, and as readily closes the temporary fissures formed by their entrance. These animalcules, and others more or less nearly related to them, may be fed artificially when under microscopical examination, by strewing in the water in which they are contained some coloured substance, such as indigo or carmine, reduced to a very fine powder. The particles of coloured matter are well seen against the usually colourless bodies of the animalcules, and the process of seizing and of digesting this artificial food can therefore be readily studied. Ehrenberg, the great German microscopist and naturalist, was the first to employ this convenient mode of observation. The food of the amœba consists of the minute vegetable organisms and smaller animalcules which inhabit its native waters; and the nutriment simply passes into the internal layer or endosarc, and is there digested.

No distinct mouth exists, and food can therefore be received by any part of the body-margin. Neither do we find any digestive apparatus or stomach-sac, such as exists in most higher animals, to be present. Around each food-particle received into the body a clear space soon forms; and when the food is dissolved or digested, this clear space

remains apparent for a time as a 'food-vacuole,' which, however, soon closes up and disappears. The food-vacuoles are in all probability caused by the presence of water or of some other fluid. If any part of the food is found to be indigestible, it is simply cast out of the body through a temporary opening formed in the ectosarc, just as when the food was received or ingested; whilst in some amœbæ a special portion of the body, named the *villous region* (fig. 2, B, *v*), has been alleged by some observers to be that by or at which indigestible portions of food are rejected.

7. **Circulation in Amœba.**—The result of the digestion of food in all living beings is to produce a fluid—named *blood* in animals, and *sap* in plants—from which the body can gain a supply of fresh nutrient matter, and thus repair the wear and tear which is inevitably associated with the act of living and being. This fluid is usually circulated throughout the body so as to bring it in contact with each tissue or part of the body; and in higher animals, the heart and blood-vessels or analogous organs perform this duty. Although the simplicity of the amœba's body forbids us to expect to find therein the perfection of detail exhibited by higher beings, it nevertheless appears probable that the contractile vesicles represent a circulatory apparatus in its most primitive state. At the moment of contraction or systole of these vesicles, tubes or canals are described by some authorities as having been observed to pass from the vesicles to the surrounding protoplasm; and we know that in certain near neighbours of the amœba—the *Infusorian* animalcules—these radiating spaces or canals actually occur. But apart from these observations, the mere fact of these vesicles contracting so regularly would strongly suggest the probability and correctness of the idea that their function is that of circulating some fluid or other throughout the organism.

Innervation of Amœba.—No traces whatever of a nervous system or organs of sense, whereby the amœba might be brought into relation with the outer world and thus gain a knowledge of its surroundings, can be discerned. That the organism can and does exercise some means of gaining

that knowledge, is evident from its behaviour to the food-particles, which it stretches out its pseudopodia to seize when they touch its body, and also from its apparently avoiding objects which lie in its miniature path, so to speak. We know that animals of much higher rank and structure than the amœba (for example, sea-anemones) appear to feel and to exhibit irritation when touched, and in many such organisms no nervous system can be detected. Even some plants may exhibit symptoms of irritability, as is well seen in the sensitive plant (*Mimosa pudica*), and the Venus' fly-trap (*Dionæa muscipula*), and nothing analogous to a nervous system has yet been discovered in plant tissues. We are therefore forced to conclude that the power of appreciating sensations may probably exist as a diffused property or attribute of the protoplasm of which the bodies of lower organisms are composed, and apart from the development or presence of any distinct nervous system.

8. **Reproduction.**—The structure and processes we have detailed as taking place in a living amœba are evidently sufficient to perpetuate the life of the single and individual animal alone. Death is continually busy in the ranks of living beings, and to repair the constant loss of individuals which thereby results, the process of *reproduction* comes into play. The process of nutrition repairs the loss of the animal viewed as an individual; the process of reproduction repairs that of the species or race. The amœba may reproduce its kind in two chief fashions. The first process, named *fission*, is that of *simple division* of the body. It is named an *asexual* process of reproduction because the elements of *sex* do not take part therein. When this process of fission occurs, we see either a single pseudopodium become detached from the amœba's body, or the body itself may divide into two parts. In either case, each separate portion moves away, and with or without a process of further growth, develops into a perfect amœba.

Then, secondly, the amœba may be seen to undergo a peculiar process known as *encystation.* In the latter case, the movements of the animalcule cease, its body assumes a rounded shape, and the ectosarc is replaced by a greatly

thickened layer or *cyst* (fig. 2, C). Hence the organism is said to be *encysted*. The nucleus and contractile vesicles disappear, and then the endosarc is observed to break up or divide into numerous little bodies, named *pseudonavicellæ* (fig. 2, D), which, when liberated by the rupture of the parent-cyst, soon appear in the likeness of young amœbæ (fig. 2, E). Whether or not this process may be termed *sexual*, and whether or not the nucleus and nucleolus may be held to represent the elements of the male and female sexes, is still a disputed point. But analogy seems to indicate that the belief in the sexual nature of this form of reproduction, is neither unwarranted nor untenable.

9. **Classification.**—The naturalist has learned to recognise different *species* or *kinds* of amœbæ, and to distinguish one species from another by differences in general form, and in the manner in which the pseudopodia are protruded, and by other characteristics. Hence he is enabled by comparison, to make a *classification* of these organisms, and to relate them to organisms with which they most nearly agree in their structure and development. A common form of amœba, for example, is the *Amœba radiosa* (fig. 1), in which the pseudopodia appear as radiating processes. In *Amœba princeps* (fig. 2, B), another species, the pseudopodia are said to be given off from a limited part of the body only; and the same character distinguishes another species—*Amœba limax*. The further extension of this principle of the recognition of likenesses, and consequent arrangement of these and allied organisms, would lead us to note a great variety of organisms essentially resembling the amœba, in the simple protoplasmic nature

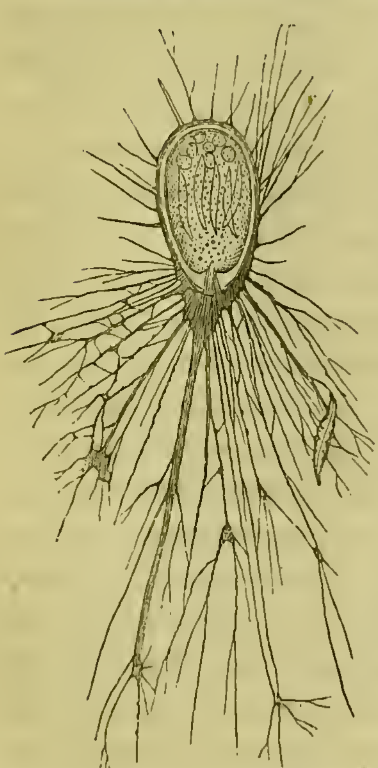

Fig. 3.—Foraminifer: *Gromia*, one of the Foraminifera, highly magnified, shewing calcareous shell, and delicate interlacing pseudopodia.

of their bodies, in their want of definite organisation, and in the general presence of a nucleus, &c. The wide relationship thus constituted, is sufficient to unite such animals to form one of the primary divisions of the animal world—known as the *Protozoa*, which group includes the *Foraminifera* (fig. 3), *Infusorian animalcules*, the *Rhizopoda* (of which Amœba is the type), *Sponges*, and some less familiar organisms.

HOW LIVING BEINGS ARE STUDIED.

10. Having regarded the amœba from the several points of view in which the zoologist must consider every living being, we may briefly try to form some estimate of the amount of knowledge we have thus obtained, and also of the manner in which that knowledge has been acquired. The thorough or *biological* examination of any living being comprehends a knowledge not only of its *morphology* or *structure*, but also of its *physiology* or *functions*, and of its *distribution* or place and sphere of *habitation*. The due understanding of any piece of machinery, such as a steam-engine, involves an almost similar collection of details. The mechanic who understands his business must know the structure of his machine, and the relations of one part to another. He may thus be said to possess a knowledge of its structure or morphology. But if the engine is viewed only as a motionless piece of mechanism, the mechanic, however perfectly he may know its structure, can hardly be said to be perfectly or thoroughly acquainted with it. The moving mass of machinery has to be very differently regarded from the motionless engine, and a new study opens before the observer, in the investigation of the active *functions* of the structures with which he has already made himself familiar. So is it with living organisms. To examine the morphology of an amœba is only to half discharge the task of the biological observer. We must also watch the organism in life, and note how the functions of its body are carried on, and how the organism thereby maintains its existence.

The *Morphology* or structure of animals and plants will

therefore include the consideration of their (1) *Anatomy*, or the structure of the fully-grown body; (2) *Development*, or the history of the changes and stages through which the organism passes in its growth from its youngest state to the adult period of existence; and (3) *Taxonomy* or *Classification*, through which we may compare and relate organisms to one another from a knowledge of their structure.

Similarly, a knowledge of the *Physiology* of any animal or plant implies an understanding of *how* organisms live, and of the three great functions which, as seen in the amœba, contribute to the maintenance of their own existence and that of their species. We therefore note (1) the *function of nutrition*, by which the animal or plant nourishes itself, or how food is received, digested, and applied to the uses of the organism; (2) the *function of reproduction*, whereby it produces new individuals competent to carry on the life of the species in time; and (3) the *function of relation or innervation*, through which the living being becomes cognisant of its surroundings, and relates itself to them through the operation of its nervous system or analogous means.

The third department of biological science is that of *distribution*. This branch deals with the habitat of animals and plants, and shews us, (1) through *geographical distribution*, or distribution *in space*, in what areas or regions of the existing world the various groups of living beings are distributed; or (2) through *geological distribution*, or that *in time*, how animals and plants were represented in *past* epochs of this world's history—epochs indicated by the arrangement of the rocks comprising the crust of the globe, and by the *fossils* or petrified remains of living things therein contained.

11. **LIFE AND ORGANISATION.**—From the examination of the amœba we may thus gain an idea of the manner in which the researches of the zoologist are to be pursued. But the investigation of the animalcule may afford an illustration of other and equally important points in connection with the study of living beings. We thus learn that, of itself, a minute speck of structureless protoplasm may con-

stitute a living organism, capable of living, as perfectly, in so far as the result to the organism is concerned, as the highest being. Then also we note that the presence of definite *structure*, or the possession of *tissues* and *organs*—shortly named *organisation*—is not necessary for the presence or maintenance of the living state. We find forms, of even lower grade than amœba—exemplified by the

Fig. 4.—Monera: *Protomyxa aurantiaca*, one of the *Monera*, or lowest Protozoa, destitute of nucleus and contractile vesicles. The animal is represented as seizing food.

Monera (fig. 4), and *Foraminifera* (fig. 3)—in which a nucleus and contractile vesicles are wanting. Thus life is not in any sense dependent upon the presence of organised structures, since these lower organisms live, literally without possessing any machinery to live with. We may observe also, in connection with this latter point, that the *vital properties* of protoplasm confer upon this substance the power not only of digesting food, but also of exercising all other functions in connection with the living state. Upon what these powers or properties depend, we do not know. At the most, we can only form some idea of the *conditions* necessary for the existence of life. Of the exact nature of

life itself we are as ignorant now as were the philosophers of the classic ages.

RELATIONS OF ANIMALS AND PLANTS.—Then lastly, we may observe in the amœba the chief characteristics which enable us to settle the identity of animals, and to distinguish them from plants. As many lower plants exhibit the power of *contractility* and of *motion* that is seen in the amœba—the former of which powers we have already noted to be an inherent property of protoplasm itself—we cannot maintain that the amœba is an animal, or, indeed, that any other organism is an animal, on these two grounds. We note also that the *chemical analysis* of animal and plant protoplasm has not as yet enabled us to detect any decided or reliable difference between the two groups of living beings. The fact that the amœba does not inclose its body within a sac or wall-membrane of the starchy substance named *cellulose*—this latter substance being found in plant-structures—may be regarded as a proof of its animal nature. But we find surer points of distinction in the fact, that, like all animals, and unlike the vast majority of plants, the amœba inhales and absorbs *oxygen*, and emits or exhales *carbonic acid;* and further, that like other animals, the animalcule can only subsist on *protein* or *organised matter*, which has already and previously been elaborated and converted into that state. The amœba, or any other animal, has no power of manufacturing new protoplasm from such inorganic materials as carbonic acid, water, and ammonia. But as plants possess this power of converting inorganic matters into protein or organic compounds, the *nature of the food* may be regarded as a reliable ground for separating animals (and with them the amœba) from their vegetable neighbours. Another and subsidiary point of distinction which might satisfy us of the amœba's animal nature, consists in the fact that food is received directly into the *interior* of the body in animals ; whilst in plants the nutritive organs consist mainly of *external* surfaces exemplified by the root and leaves. The entire animal world, it may be lastly noted, comes to be ultimately dependent for support on plants ; since animals obtain from plants the

ready-made protein compounds required for the maintenance of their frames. And strange as it may appear, the lion, flesh-feeder though the 'king of beasts' may be, is in reality dependent upon the grasses on which he treads. Since the flesh of the antelopes and other game on which he subsists, merely represents so much vegetable matter modified and converted into animal tissue. The annihilation of plants, would thus in truth mean and include the utter extinction of animal life.

CHAPTER II.

THE HYDRA, OR COMMON FRESH-WATER POLYPE.

12. **DIFFERENCES BETWEEN DIFFERENT ANIMALS.**—When we compare the amœba as an animal belonging to a low grade of structure with more highly organised beings, the differences between the compared organisms are seen to consist of two sets or kinds. Animals differ from one another either *morphologically*—that is, in the *structure* of their bodies; or *physiologically*—that is, in respect of the degree of perfection in which the functions of their bodies are performed. One animal, in other words, is said to be higher than another, because, on examination of the body of the former, we find certain principles therein represented, to which the names *morphological type* and *specialisation of function* or *physiological division of labour* have been applied. The lower animal, on the contrary, does not exhibit these principles, for the due illustration of which we may select one or two very simple but typical animals belonging to a group of the animal world known as the *Cœlenterata*.

13. **EXAMINATION OF HYDRA.**—Attached to the duck-weed and other plants which grow in our ponds and ditches, certain small animals, scientifically known as *Hydræ*, and popularly as the 'Common Fresh-water polypes' (fig. 5), may be found in plenty, especially in the

warmer months of the year. If water, along with confervæ or the lower vegetable organisms which float on its surface, be taken from a stagnant pool, and allowed to remain in a clear glass vessel, the hydræ which are therein contained, will be found to have clustered on the side of the vessel next to the light. These little organisms may be distinguished by the unassisted sight, and may attain a maximum length of half an inch. More commonly, however, they are of smaller size. Each hydra presents for examination a little tubular body, fixed to the duckweed or other matter by one extremity — which may be named the *proximal* end or *hydrorhiza*—and possessing at the unattached or *distal* extremity a *mouth*, surrounded by a circle of larger or shorter *tentacles* or *feelers*, numbering from four to ten, or even more. The body may be coloured green or brown; the former colour being due to the development of the same substance —*chlorophyll*—which gives to plants their green hues. The organism thus described, including a mouth, tentacles, and body-cavity, is known to zoologists as a *polypite;* this latter term being applied to the nutritive element in the body of all animals allied to the hydra; whilst the entire organism and body of the hydra, or any of its allies, is named the *hydrosoma*.

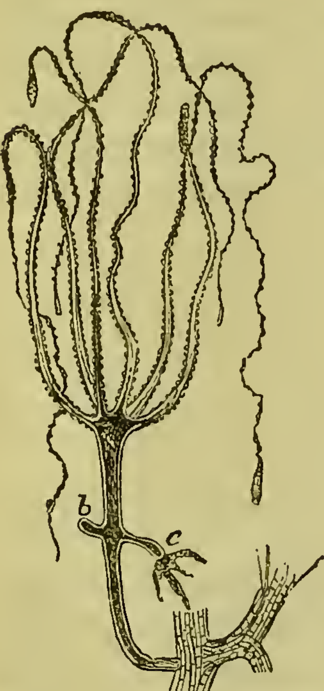

Fig. 5.—Hydrozoa: *Hydra fusca*, the 'Long-armed Hydra,' shewing a young bud at *b*, and a more advanced bud at *c* (magnified).

When a hydra is touched or irritated, we observe the tentacles to be temporarily withdrawn, and the body also for a time to contract upon itself. The organism, therefore, possesses means for receiving and acting upon *sensations*, and thus exercises in some way or other the function of *relation* or *innervation*. The hydræ are not permanently rooted to fixed objects, but possess the power of moving about in the

water. They may be observed to crawl somewhat after the fashion of leeches, by alternately fixing the mouth and root; whilst occasionally they may be met with floating on the surface of the water they inhabit.

14. **Structure and Histology of Hydra.**—The morphology of the hydra may be very easily understood. The tubular body, when microscopically examined, is found to be composed of two layers or membranes, closely apposed. The outer layer is named the *ectoderm* (fig. 6, A, B, *ec*),

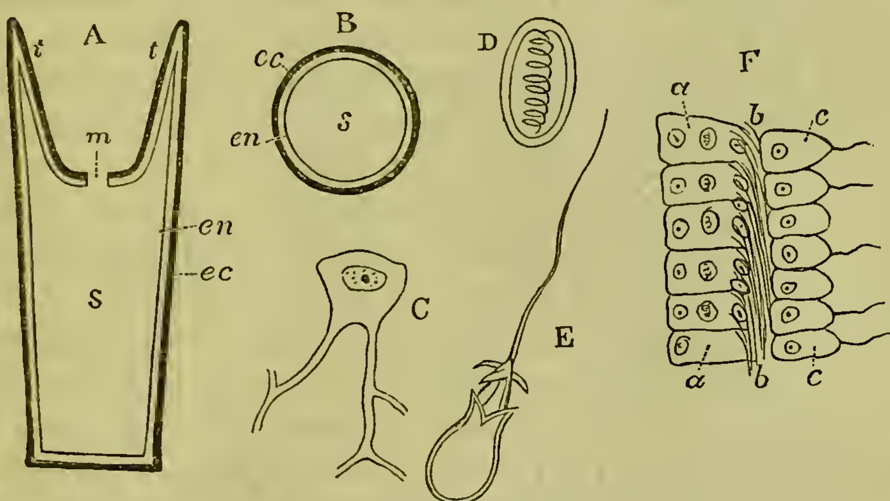

Fig. 6.—Morphology of Hydra: A, longitudinal diagrammatic section of Hydra; *ec*, ectoderm; *en*, endoderm; *m*, mouth; *s*, somatic or body-cavity; *t*, *t*, tentacles. B, transverse section of hydra (references as in A). C, one of the cells of the ectoderm largely magnified, shewing the processes of the cell. D, a 'thread-cell' in its normal state. E, the thread-cell of hydra, with thread everted. F, microscopic section of body-wall of *hydra; a*, cells of *ectoderm; b*, middle layer (*mesoderm*), formed by internal processes of ectodermal cells; *c*, cells of endoderm, some bearing cilia. The nuclei and thread-cells are shewn in the cells of the ectoderm, and nuclei in those of the endoderm.

and the inner is known as the *endoderm*, *en*. The latter forms the lining membrane of the interior of the body-cavity or *somatic* cavity (fig. 6, A, *s*), as it is termed; and the tentacles, *t*, which are hollow organs, consist of simple tubular extensions of the cavity of the body, and are each composed of ectoderm and endoderm layers. The more minute or microscopic examination of the layers of the hydra's body, shews that each membrane is made up of certain minute elements named *cells*. These

cell-elements in various and diverse ways form all the tissues and organs of animals and plants. The cells of the ectoderm (fig. 6, C, and F, *a*) in the hydra are tolerably large. They each contain a *nucleus* or solid particle, and are hence named *nucleated;* whilst they appear to give off prolongations or processes from their inner surface (fig. 6, C, F), or that next the endoderm. Smaller ectodermal cells, F, *b*, seem to lie between these processes; and within the cells of both ectoderm and endoderm, certain other remarkable cells or capsules, known as *thread-cells*, *cnidæ*, or *nematocysts* (fig. 6, D, E), are seen to be contained. The nature and uses of these thread-cells, which are especially numerous on the tentacles, will be presently explained, when treating of the physiological processes of the hydra.

The endoderm, or inner layer of the body (fig. 6, F, *c*), is, like the ectoderm, composed of flattened nucleated cells, arranged in a single layer, and sometimes provided with delicate eyelash-like processes named *cilia*. Some observers have, in addition, described a layer of cells lying between the ectoderm and endoderm, and probably formed by a modification of the cells described as existing between the processes of the ectodermal cells. This layer, more specially developed in many allies of the hydra, is known as the *mesoderm* or middle layer (fig. 6, F, *b*), and appears to be the seat of the contractile or muscular movements which the hydra and its neighbours exhibit. From this latter fact, the layer has sometimes been named the *muscular layer* or *stratum*. Thus, then, we may compare the hydra's body to a simple tube (fig. 6, A, B), inclosing a cavity which is destitute of any internal organs or contents; the tube being formed of two chief layers or membranes, *ec*, *en*, composed of cells, one of which membranes, *ec*, lies next the water, whilst the other, *en*, forms the lining of the body-cavity, *s*.

15. **Nutrition of Hydra.**—The process of nutrition in the hydra includes the prehension or seizure of food by the tentacles. These animals feed upon the minute water-fleas and other small organisms which live in water; and when such a body comes in contact with the tentacles, these filaments seize the prey, and draw it towards the

mouth-opening which exists between them. The prey may be seen at first to struggle violently against its fate, but it appears very soon to become paralysed and helpless. The cause of this latter event is readily explained by an examination of the peculiar thread-cells already mentioned as existing both in the tissues of the tentacles and of the body. Each thread-cell contains fluid, and consists of a little oval sac or bag (fig. 6, D), formed of a tough outer layer, and lined by a more delicate membrane. The latter is extended at the apex or narrow end of the cell to form a delicate thread or filament, which is coiled up within the cell, and from the presence of which the structure derives its name. When such a cell is irritated in any way, as by pressure, the outer layer of the cell bursts, and the thread is everted or thrown out (fig. 6, E) along with the fluid-contents. The base of the thread in the hydra's cells (fig. 6, E) is armed with three barbs; and the entire structure and phenomena connected with these cells, forcibly suggest the idea that each represents a kind of stinging or poison-apparatus, whereby the prey is paralysed or killed. Each thread-cell, when discharged or ruptured, is useless for further offence; the capsule being absorbed, and new cells developed to replace those which have performed their function. It is noteworthy to observe, that the stinging powers of many Cœlenterate organisms—such as the Jelly-fishes (*Medusidæ*) and Portuguese men-of-war (*Physaliæ*)—are found to be due to thread-cells exactly resembling those of the hydra in their essential nature and structure.

The food thus seized by the tentacles, and paralysed, in the case of living prey, by the thread-cells, is dragged towards the mouth and passes into the general cavity, *s*, of the body into which the mouth (fig. 6, A, *m*) opens. The hydra thus possesses no stomach or cavity specially devoted to the reception and digestion of food; these functions being performed by the simple interior of the body, *s*, which is entirely destitute of organs, and which is lined, as we have seen, by the endoderm. Here the food is digested or submitted to the action of certain fluids secreted by the

endoderm. The indigestible parts of the food are cast out of the body by the mouth; no distinct anal aperture or vent existing for the rejection of waste products.

As no specialised digestive system exists, so no special organs are developed for the *circulation* of the nutritive fluid manufactured by digestion from the food, and which corresponds to the blood of higher animals. It is probable, however, that the nutritive fluid undergoes a process of circulation and diffusion through the tissues of the hydra's body; since it is from the materials afforded by this fluid, that the tissues are enabled to form new substance, and to increase and grow. No traces of a nervous system can be demonstrated in the hydra, but nevertheless, as already remarked, it possesses the power of feeling, and exhibits the phenomena of irritability; shrinking when touched, and being acutely sensible of the contact of prey with the tentacles. As in the amœba, therefore, we may say that the nervous sense exists in hydra in a diffused state, and appears to reside in the tissues generally, or apart from any specialised nervous system.

16. **REPRODUCTION.**—The reproductive cycle of the hydra's life exhibits certain phases of a highly interesting nature. These animals may reproduce their like either *asexually* or *sexually*. The asexual processes are represented by *fission* or *division* of the parent-body into new beings, as in amœba; and by *gemmation* or *budding*, whereby new beings are developed in the form of buds or *gemmæ* produced by the parent. The process of fission does not appear to occur very frequently in the natural life of the hydra, but it can be artificially performed with marked success. A certain Mr Trembley, who resided at Geneva, published in 1744 his researches on the artificial propagation of these animals by fission or division of their body-substance. Trembley found that he could divide these organisms into halves, and even into much smaller portions, when each part grew into the form of and reproduced a perfect hydra. The animal's powers of reproduction through this artificial mode of propagation appear indeed, like those of its mythological namesake, to be almost

illimitable. Trembley actually succeeded in turning several specimens inside out, so that the ectoderm took the place of the endoderm, and *vice versâ;* this latter process not interfering with the vitality of the hydræ, some of which succeeded in returning to their original and natural condition; whilst others, less fortunate, seemed to entirely accommodate themselves to the exigencies of their unwonted state.

Gemmation or Budding.—Reproduction by *budding* may occur throughout the whole or greater portion of the year. When this process occurs, a little protuberance (fig. 5, *b*) is seen to form on the side of the body, most frequently near the *hydrorhiza* or attached extremity. If examined at an early stage, this little bud is found to consist of a simple protrusion of the ectoderm and endoderm of the parent body. As it grows, it comes to contain a process of the parental body-cavity; and soon a mouth opens at the free end of the bud, whilst little tentacles begin to sprout around the mouth-opening. A young hydra (fig. 5, *c*) is thus, in short, seen to be produced by a literal process of budding from the parent form; and when the relations of these two connected organisms are investigated, the body-cavities of the parent and offspring are seen to communicate with each other, so that the hydra now appears as a double organism (fig. 5), including two body-cavities and fed by two distinct mouths. The first bud thus produced may develop a bud in its turn, and three or even more generations of hydræ may sometimes be seen adhering together and forming a compound animal. But the connected or compound state of hydræ is never permanent. Sooner or later, or at periods ranging from three or four days to as many months, the buds break contact with and drop away from the parent body; and, after attaching themselves, begin life on their own account; whilst the aperture of attachment in the parent body closes up, and the organism resumes its single state. The process of budding as exemplified by the hydra is named *discontinuous*, from the buds becoming finally detached from the parent; the opposite condition, in which the buds remain permanently attached to form a compound organism —as in Zoophytes—is known as *continuous* gemmation.

17. **Sexual Reproduction.**—In the preceding modes of reproduction—fission and gemmation—the elements of *sex* do not participate. The third process is named *sexual* from the fact that two products, each furnished by a distinct structure or sex-organ (*male* or *female*), participate in the formation of the new being or beings. Towards the close of the summer or during autumn, certain little processes of conical form (fig. 7, A, *s*, *s*) are developed at the bases of the tentacles. These are named the *spermaria* or *testes*. From the cells of which these organs are composed, little actively moving bodies named *spermatozoöids* (fig. 7, C) are developed, and

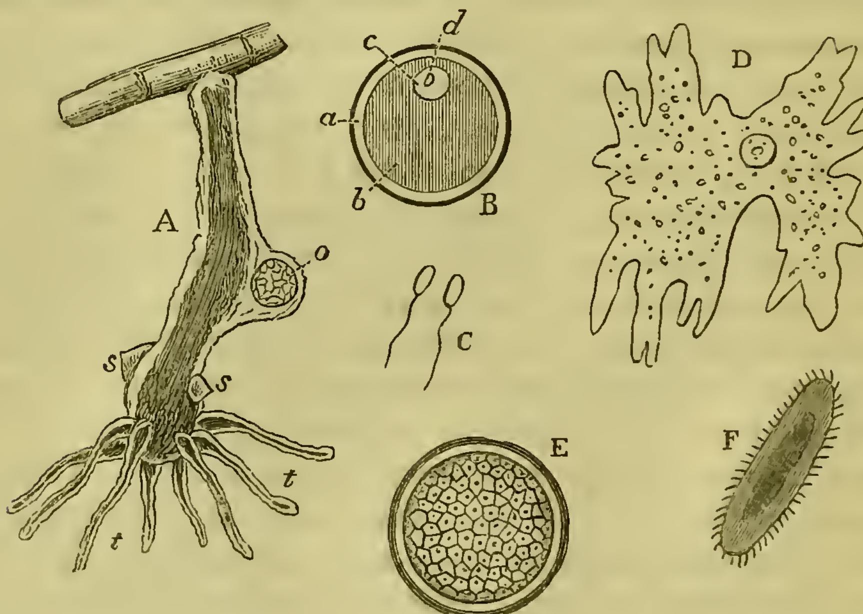

Fig. 7.—Development of Hydra: A, *Hydra vulgaris*, largely magnified, shewing the ovarium with contained egg at *o*; spermaria, *s*, *s*; and tentacles, *t*, *t*. B, diagram of an ovum or egg: *a*, vitelline membrane; *b*, vitellus or yolk; *c*, germinal vesicle; *d*, germinal spot. C, spermatozoöids of hydra (magnified). D, egg of hydra, shewing the germinal vesicle and germinal spot. E, *morula* or mulberry-stage of egg-development in hydra. F, *planula*, or free-swimming embryo developed from the egg of *Cœlenterata* generally.

escape into the surrounding water by the rupture of the spermarium. Nearer the base or root of the body one or more rounded bodies are developed of larger size than the spermaria. Each of the rounded growths (fig. 7, A, *o*) is named an *ovarium* or *ovary*, and contains a single *ovum* or

egg, which presents essentially the structure and characters of a nucleated cell. Thus the egg of hydra consists of an irregularly-shaped mass of protoplasm (fig. 7, D), not unlike an amœba in general appearance, forming the *vitellus* or *yolk*. This yolk (fig. 7, B, *b*) is surrounded by a vitelline membrane, and contains a nucleus named the *germinal vesicle*, *c*, and a nucleolus, *d*, known as the *germinal spot*. The ovum appears to be formed by a modification either of the cells of the ectoderm, or of those cells which lie between the latter layer and the endoderm. And the likeness of the egg to a large nucleated cell, may be demonstrated by comparing the ovum (fig. 7, D) to the cell of the ectoderm depicted at C, fig. 6.

Development of Hydra.—This egg is destined to give origin to a young hydra, but before the necessary process of *development* can take place, the ovum requires to be *fertilised* by contact with the spermatozoöids from the spermarium. This process of fertilisation of the animal egg, is exactly analogous to the fertilisation of the *ovules* or seeds of plants by contact with the *pollen* from the stamens. As the result of that contact—of the true nature of which science as yet knows literally nothing—the egg passes through certain phases or changes, which together constitute its *development*, and as the result of the latter process, a new being is duly evolved. Briefly traced, the history of development in the hydra begins after fertilisation, with the segmentation or division of that part of the egg known as the *yolk*, this process resulting in the conversion of the yolk into a *mulberry-like mass* of cells (fig. 7, E), known as the *morula*-stage of development. The outer cells of this mulberry-mass are cylindrical, and the inner ones polygonal in shape. A case, often rough or spiny on its outside surface, now forms around the egg, and at this stage it detaches itself from the parent-body; whilst the cells of the yolk, or morula, fuse together or unite to form the structure named the *blastoderm*. This latter next divides into two layers—the outer or *epiblast* becoming the ectoderm, and the inner or *hypoblast* forming the endoderm of the future animal. At this stage the *embryo* or young animal

is known as a *planula* (fig. 7, F), and consists of the ectoderm and endoderm inclosing a central space—the future body-cavity of the hydra. A mouth is next formed at one extremity, the embryo now being named a *gastrula;* tentacles begin to be developed around the mouth-opening; and with the fixation of the lower extremity of the body, and the process of ordinary growth, the embryo develops into the mature hydra.

Species of Hydræ.—The species of hydræ most familiar to naturalists comprise the Common Hydra (*Hydra viridis*), with a green body and short tentacles; *H. vulgaris* (fig. 7, A), with a brown body and tentacles of moderate length; and *H. fusca* (fig. 5), a larger species, coloured of a deep brown tint, with very long tentacles, and hence known popularly as the 'Long-armed Hydra.'

18. **CHARACTERS OF CŒLENTERATE ANIMALS.**—By the examination of the hydra, the essential characters of the *Cœlenterata*, or great subdivision of the animal world to which this animal belongs, may be readily illustrated. This sub-kingdom or type of animal structure may be regarded as ranking next in order and above the Protozoa, to which latter group the amœba belongs. And the characters which may be regarded as distinctive of the hydra and all other Cœlenterata, are to be found firstly in the higher development of the body-tissues, as compared with those of the Protozoa, to form the two layers, ectoderm and endoderm, already noted as occurring in the hydra. We thus note also that the higher structure or *type* of the hydra has resulted in the production of *cells* as the veritable elements of which its body is built up. And hence we name the hydra a *cellular* organism or body; this condition being unrepresented in the amœba, and doubtfully in any other Protozoön. We thus also become aware of the fact, that the type of structure of the hydra's body is superior to the simple plan on which that of the amœba may be said to be built up. This latter fact illustrates what zoologists mean when they say that the *morphological type* of one animal is higher than that of another. A second character of Cœlenterate animals consists in the imperfect nature

of the digestive system. As we have noted, the general body-cavity of the hydra (fig. 6, A, B, *s*) serves for an alimentary sac; food being therein digested and assimilated. And as the term 'Cœlenterata,' in the abstract at least, implies that the digestive system and general cavity of the body are in free communication with each other, this condition is certainly represented in the hydra, where these two cavities are identical. In the sea-anemones, the structure of which will presently be considered, the meaning and application of the name 'cœlenterate' will be even better understood than in the hydra. As subsidiary to the character afforded by the imperfect or unspecialised nature of the digestive system, it may also be noted that no cœlenterate develops a *hæmal* or blood-vascular system, consisting of heart and blood-vessels; whilst, save in a few of the higher members of the group, no traces of a nervous system are to be perceived. A third character of cœlenterate animals is found in the presence of the cnidæ or thread-cells, or those peculiar stinging-cells, imbedded in their tissues. These cells are found to occur in several other groups of animals; but in their most typical development they are characteristic of the group represented by the hydra and its neighbours. A fourth and last feature of cœlenterate animals exists in the characteristic *symmetry* of their bodies. The symmetry of animal forms means the result of the arrangement of the separate parts or segments—real or ideal—of which they may be regarded as composed. Thus we find all cœlenterate animals to exhibit what is known as *radial symmetry*—that is, they have the parts of the body arranged radially, or around a central point formed by the mouth. A glance at the body of a sea-anemone, or even at that of the hydra, will shew this feature of their organisation. And the Cœlenterata are also said to possess *bilateral* symmetry, since their bodies can also be theoretically divided into two equal halves by a line passing vertically through the body.

19. **COMPARISON OF HYDRA WITH AMŒBA.**—The superiority of the hydra and its neighbours over the amœba and its kind may also be illustrated by the principle

already alluded to, and which is known as the *specialisation of functions*, or as the *physiological division of labour*. We have already seen that the morphological type of the hydra is of a higher and more elaborate description than that of the amœba. We now note that, along with the superiority of structure, there also exists a greater complexity of the functions in the hydra's body. In the amœba, for example, any part of the body received the food, just as any part digested the nutriment. The digestive system and functions in the amœba are therefore said to be *unspecialised*. But in the hydra special organs or tentacles are developed for seizing the food, and a special body-cavity set aside or specialised for its digestion. And whilst in the amœba the true reproductive organs were doubtfully distinct, in the hydra these organs are perfectly specialised. Thus we say that *specialisation* or *differentiation* of the functions of digestion and reproduction exist to a certain extent in hydra, and that consequently it is to be regarded as of higher type or kind than the amœba. In other words, the physiological labour or functions of the hydra's body are not, as in amœba, thrown upon one tissue—the common protoplasm—but the labour is divided, and the included functions allocated to different organs. The amœba, to use a homely comparison, represents the general servant of a small household, on whom devolves all the duties of the house; whilst the hydra represents a household, employing an increased number of servants, each of whom has his or her special duties to perform. In animals higher than the hydra, this principle of the 'physiological division of labour' is carried to a still greater extent. In a fish, for example, the digestive system would be found to include a distinct stomach and a large number of additional organs, each performing a special function in the work of digestion. Whilst the development in higher animals of a heart and blood-vessels and of other organs, similarly represents a further illustration of the fact that superiority in animal structure results, firstly, from the development of numerous structures or a higher morphology; and secondly, from these structures bearing each a part in the complex functions or physiological labour of the

body—a labour performed by the simple protoplasm of the lower amœba and its kind. It may lastly be noted, that some animal forms evince a *retrogression* or physiological backsliding in the course of their development; this process of retrogression being exactly the reverse of specialisation of functions and organs. Thus, in their young state, the *Barnacles* and allied *Crustaceans* are free-swimming, active forms, and possess many organs and structures, which disappear when they attain their adult condition. Most *parasitic* animals also lose structures and organs on attaining their full growth. Hence retrogression, tending to simplify organs and parts, is viewed as opposed to specialisation, which tends to multiply and increase the structures of animals.

True Reproduction.—The specialisation of the reproductive function in hydra leads us to note the essential nature of that function in its sexual or highest aspect. This aspect we have seen to include the formation of an ovum or egg (fig. 7, D), and its fertilisation by the male element (fig. 7, C), whether these elements be provided by one or two individuals. The single hydra furnishing both elements for the production of a new being, is termed *monœcious;* whilst the name *diœcious* is applied to those organisms in which the elements of sex exist in separate (male and female) individuals. The process of true reproduction is seen to be essentially different in its nature from the other modes observed in hydra—namely, gemmation and fission, in which the elements of sex are entirely unrepresented.

20. **The Animal Nature of Hydra.**—The *animal* nature of the hydra, whilst sufficiently evident, may be inferred from the same sources as those which determined the nature of the amœba. Thus, for example, the cells of the hydra's body are not inclosed within walls or envelopes of the starchy matter, named *cellulose*, which is found in the cells of plants. The hydra and its cells can subsist only on already-formed protein or organised material; this feature being, as already remarked, a truly animal characteristic. The hydra further absorbs oxygen, and emits carbonic acid like other animals. It is also noteworthy

that the green colouring matter, or *chlorophyll*, of some species of hydra, is essentially similar to that of plants; but this fact, whilst shewing the futility of mere chemical distinctions between animals and plants, does not invalidate the grander distinctions between them, founded on the nature and manner of assimilation of the food.

CHAPTER III.

ZOOPHYTES; AND THEIR LIFE-HISTORY.

21. **Relations of Hydra to Zoophytes.**—In the Hydra, the process of gemmation or budding was observed to be discontinuous in its nature; the buds remaining attached to the parent-organism for a longer or shorter period, but ultimately breaking contact with the latter, and leading an independent existence. This process of budding becomes exceedingly interesting to the naturalist, inasmuch as it serves to explain the nature of some curious organisms nearly related to the hydra, and which are familiarly known as *Zoophytes*. The hydra belongs to a group or class of Cœlenterate animals named *Hydrozoa*. The remaining and second class of Cœlenterata, represented by the sea-anemones, coral polypes, and the like, is known as that of the *Actinozoa*. The respective characters of the two classes may be discussed when the structure of the sea-anemone has been examined;

Fig. 8.—Morphology of Zoophyte: *Sertularia nigra* (*Diphasia pinnata*), one of the 'Sea-Firs,' shewing the plant-like form of the organism, with gonophores or reproductive buds borne on the lateral branches. *a*, a small portion enlarged, shewing the cells or *hydrothecæ*, which contain the zoöids.

but it will suffice for the present to note that the zoophytes are included in the former of these two classes, of which, indeed, the hydra forms the type.

The more common forms of zoophytes are represented by such organisms as the *Sertulariæ* or 'sea-firs' (fig. 8), and by many other forms, which are found in abundance amid the *rejectamenta* or refuse of the sea-beach, or which may be discovered in a living state, attached to the broad fronds of

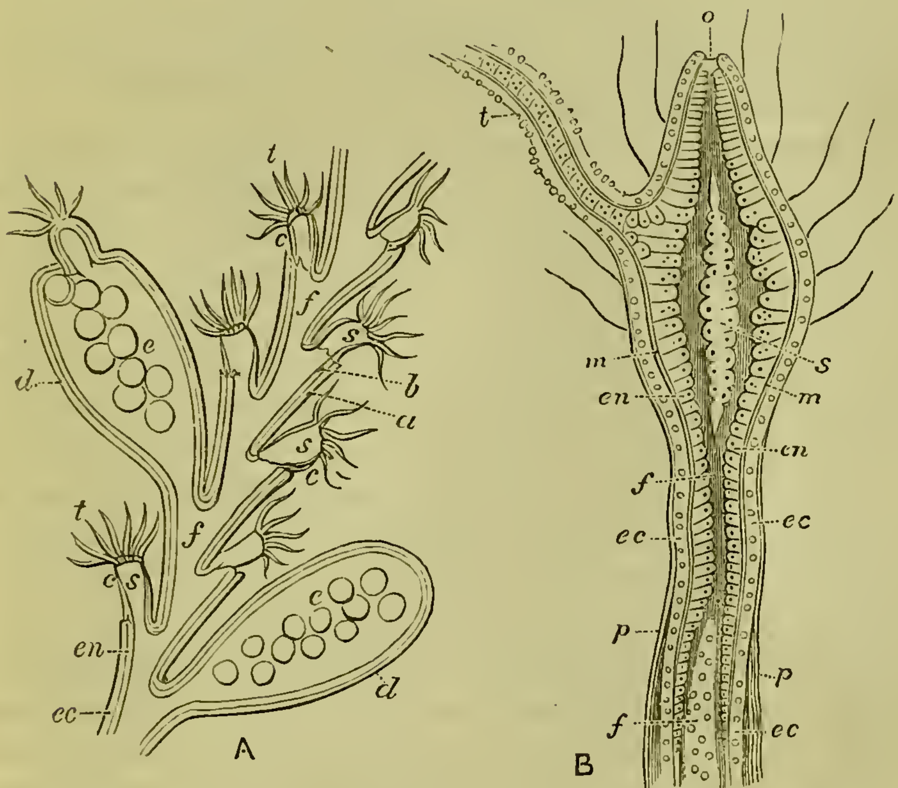

Fig. 9.—Morphology of Zoophytes: A, Diagrammatic figure illustrating the structure of *Sertularia; ec*, ectoderm; *en*, ciliated endoderm; *c*, *c*, ordinary nutritive zoöids or polypites, inclosed in hydrothecæ; *d*, *d*, reproductive zoöids or gonophores, the upper one most fully developed, and both containing ova, *e*, *e*; *f*, internal and general cavity of the cœnosarc; *s*, *s*, body-cavities of the polypites freely communicating with the hollow cœnosarc, *f; t*, *t*, tentacles. B, magnified section of a single polypite of a zoophyte (*Cordylophora*); *m*, muscular layer of body; *o*, mouth; *p*, polypary or hard outer layer of ectoderm; other references as in fig. A.

tangle, or fixed to the shells and stones obtained by the dredge. When such an organism is cursorily examined, the observer may have some difficulty in persuading himself

that he is regarding an *animal* organism; since in outward form it closely resembles a plant, as, even in its life-history, it mimics many of the features of the vegetable world. Thus one of these zoophytes (fig. 8) may be seen to present us with a rooted organism, firmly attached by one extremity to a stone or other fixed object, and developing branches and structures which will correspond to buds; whilst if we microscopically examine the organism in its living state, we shall find that each branch bears numerous living beings, each possessing a mouth (fig. 9, A, *c*, *c*, and B, *o*), surrounded by tentacles, and resembling a little hydra in appearance and in all essential details.

22. **Morphology of Zoophyte.**—If we inquire into the constitution of such a literal colony of animal forms, we may readily form an accurate idea of its nature by referring to the process of gemmation or budding already observed in the hydra. If we suppose a hydra-like body to possess the power of producing buds, and further conceive that these buds—instead of being, as in hydra, discontinuous, and separating from the parent-body—develop into beings resembling the parent, and which remain permanently connected together to form a compound organism or colony, we shall have formed a correct idea of the nature of a zoophyte. Thus a zoophyte is essentially a compound hydra, which has multiplied itself by a process of continuous gemmation, and has thus become a compound organism.

A more detailed examination of one of these curious animal-colonies presents us, firstly, with an organism named as a whole the *hydrosoma*, and which consists of a main stem or *hydrocaulus*, and of branches attached thereto. The medium forming the stem and branches, and which thus binds the various parts of the colony together, is named the *cœnosarc* (figs. 8 and 9); and this structure frequently develops an outer layer of horny texture, known as the *polypary* (fig. 9, B, *p*). The hydrosoma or entire zoophyte is fixed, like the hydra, by a root or *hydrorhiza*; and the name *proximal* extremity is given to its attached end, while the opposite and freely growing portions are known as the *distal* parts.

The microscopic investigation of the zoophyte shews that the cœnosarc forming the stem and branches is hollow (fig. 9, A, B), and is in free communication with the body-cavities (fig. 9, A, *s*) of the little organisms which compose the colony. Each of these organisms, or *polypites* as they are named, is comparable to a little hydra, and is contained, in the case of the Sertularidæ or 'sea-firs,' in a little cup-shaped expansion of the cœnosarc, named a *hydrotheca* (fig. 9, A, *c*). From this hydrotheca the little organism can protrude its tentacles, *t*, *t*, at will; the latter organs being delicate thread-like structures, disposed in a single row around the mouth. The body-tissues of each little organism consist of ectoderm (fig. 9, A, B, *ec*), and endoderm, *en*, as in hydra; and these form and line a little body-cavity, which, as in the latter form, is destitute of any organs, and serves as the cavity (fig. 9, A, B, *s*, *s*) for the reception and digestion of food. The body-cavity of each little member of the colony opens below into the hollow cœnosarc (fig. 9), forming the stem and branches, so that the latter structures may be viewed as mere prolongations of the body-cavities of the organisms. The ectoderm, *ec*, and endoderm, *en*, are also found to be continued downwards and throughout the entire organism (fig. 9, B), and form a lining membrane to the cœnosarc and its branches. Thus every part of this animal-tree is brought into contact with every other part through the medium of the hollow stem and branches. The characteristic 'thread-cells' are also developed on the tentacles (fig. 9, A, B, *t*), and in other parts of these organisms, and serve, as in Hydra, to paralyse the prey caught by the tentacles.

23. **Physiology of Zoophyte.**—The life-history or physiology of a zoophyte may be found to bear a close analogy to the life of a true plant. Thus each little polypite or hydra-like member of the colony captures food by aid of its tentacles, digests that food within its body-cavity, and thereafter transmits the nutritive fluid to the hollow cœnosarc, through every part of which it undergoes a circulation. Each member of the colony, in fact, helps to manufacture the common stream of nutriment from which

it in turn derives its own supply of food; and we thus meet with an excellent illustration of the principle of unselfish co-operation of many different organisms to one great end. The circulation of fluid through the cœnosarc is carried on partly or wholly by means of vibratile cilia, similar to those which line the endoderm of hydra. The due nourishment of the colony being thus provided for, we find that the constant losses sustained by the death of the little polypites are made good through the same process of continuous budding which produced the colony at first. And thus, like a tree producing new leaves, the zoophyte develops new buds; and as by the circulation of its sap the plant provides for its due nutrition and growth, so the zoophyte elaborates and circulates the nutritive fluid throughout its entire structure.

24. The compound organism, as far as we have regarded it, may be said to consist of a connected assemblage of like beings or *polypites*, each of which is devoted to the nutrition of the organism, and is capable of producing its like by gemmation or budding. To the entire assemblage of such organisms in a zoophyte, the name of *trophosome* is applied. A little consideration, however, will shew that the entire life-history of the zoophyte has not yet been reviewed. The trophosome with its powers of nutrition and budding can only provide for the life of the *single* zoophyte. It cannot give origin to new zoophytes. A plant may be seen in due time to produce reproductive organs or *flowers*, which, through the production of seeds, give origin to new beings. If the zoophyte's constitution be complete, or if our scientific survey be of a complete and final character, we must shew that, like other organisms, it can produce new forms, which will continue the existence of the species in time, and make good the death of the entire organism, just as the process of budding repairs the partial death of each zoophyte.

25. **Reproduction of Zoophyte.**—The continued observation of the zoophyte shews that sooner or later in its history certain buds of a kind different from the polypites are duly produced. In their simplest form, as in Sertulariæ, these buds

are seen to consist of urn-shaped processes (figs. 8 and 9, A, *d*, *d*) borne on the branches, and named *gonophores*. These gonophores may be inclosed like the polypites in cups named *gonothecæ*, and may also be supported on processes termed *gonoblastidia*. They develop within them the male and female reproductive elements (fig. 9, A, *c*, *c*), and to the entire set of gonophores or reproductive buds of a zoophyte-colony, the name *gonosome* is applied; this designation being used in contradistinction to that of 'trophosome.' The ova or eggs of the gonophores being duly fertilised as in hydra, pass through essentially similar stages in their development. From the segmented egg, the embryo or young form makes its appearance as a *planula* (fig. 7, F), or free-swimming, ciliated body, which, after living an independent existence for a time, settles down, attaches itself to a fixed object, and develops a single little polypite or hydra-like body. This primary polypite soon begins to bud; and the buds remaining permanent and attached to the parent-polypite, the embryo gradually develops into the compound zoophyte similar to that which gave it birth.

Whilst this simple reproductive history is observed in many zoophytes, that of many species of these organisms exhibits more interesting and more complicated phases. In the latter case, the reproductive bodies appear in the form of little *Medusæ* or 'jelly-fishes' (fig. 10, A, *b*, *b*), and are hence named *gonozoöids* or *medusiform gonophores*. Each of these medusæ-buds presents merely a modification of the little hydra-like polypite; the proximal or attached extremity of the reproductive bud developing a clear, jelly-like, bell-shaped body, swimming-disc, or *nectocalyx* (fig. 10, B, *n*); whilst the mouth opens at the extremity of a hollow process, *m*, which, like the clapper of the bell, depends within its interior, and is named the *manubrium*. This manubrium is the modified polypite, and from its base canals, *r*, *r*, radiate through the substance of the bell to unite in a circular canal, *c*, surrounding its mouth; these canals representing extensions of the body-cavity of the modified polypite. This medusa-bud sooner or later separates from its

zoophyte-parent, and swims through the water by expanding and contracting its bell-shaped body, which is partially closed below by a membrane named the *velum* or *veil*, *v*. It lives a free and independent existence for a time; and we may thus recognise in many of the beautiful little jelly-fishes, common in the summer sea around our coasts, the free-floating, reproductive buds of fixed and rooted zoophytes.

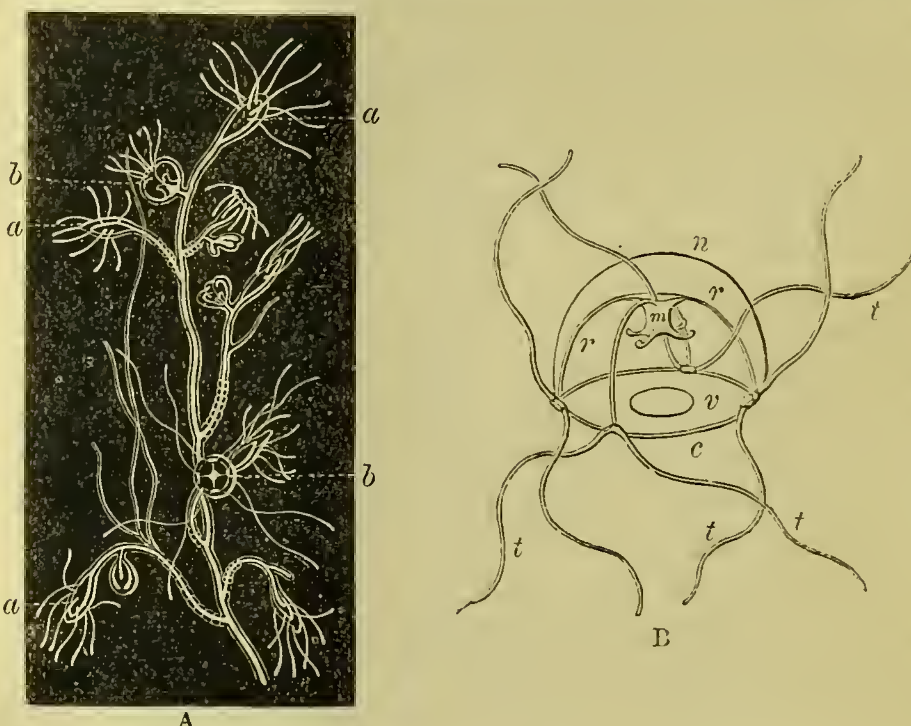

Fig. 10.—Reproduction of Zoophytes: A, enlarged figure of *Bougainvillea superciliaris*, shewing ordinary polypites at *a*, *a*, and medusoid gonophores at *b*, *b*. B, one of the medusoid gonophores of A; *c*, circular canal; *m*, manubrium; *n*, nectocalyx or swimming-bell; *r*, *r*, radial canals; *t*, *t*, tentacles; *v*, veil.

Curiously enough, the medusa-bud may in some cases give origin to new medusæ by a process of budding; but its true mission is to produce the male or female reproductive elements. By the union of these, fertilised eggs are developed, and the medusa dies, its functions having been fulfilled. From each egg a single polypite is produced; and this polypite, by the process of continuous gemmation, gives origin to the compound and rooted zoophyte (fig. 10, A) from which the free-swimming medusa sprang.

NATURE OF ZOOPHYTES.

26. The study of the zoophyte has brought under our notice an animal differing from the amœba and hydra, in that it is of *compound* nature. The life-history of such a being, however, is seen to be in no way different from that of an ordinary and single animal. That history exhibits a nutritive and reproductive portion; the process of nutrition being more specialised than in the hydra, in that it is performed by distinct organisms; whilst similarly the reproductive process devolves upon specially developed parts of the animal. The close identity of these apparently distinct elements in the compound being is, however, proved by the study of their development. The reproductive buds or gonophores are found to be simply modified polypites; a fact proved by the gonophore in some cases becoming a polypite after discharging its contents. So that in reality there exists a singular unity of organisation throughout the apparently dissimilar series of beings included in the zoophyte.

27. **COMPOUND AND SIMPLE ANIMALS.**—The history of the zoophyte serves as an appropriate illustration of certain important zoological facts and ideas involved in the comparison of compound with single animals; and also aids in the comprehension of the true nature of the somewhat complicated reproductive history just detailed. As the higher animals each exist in a single state, and represent each a single form, there can be no hesitation in applying to such beings the term *individuals*. But with many lower animals exemplified by the zoophytes or *Hydrozoa*, and by other organisms, the case is altered; since we observe such beings to consist of an aggregation of forms, united more or less completely, as we have seen, into an animal-colony. The question of the nature of these compound beings, when compared with higher and single animals, thus arises. And we may therefore seek to know if *each member* of the compound organism corresponds to the single higher animal; or if, on the other hand, the *entire colony* represents the latter form.

In other words, we thus seek to determine what is an *individual* animal, zoologically regarded. The best exemplification of the individual form is certainly to be sought for among the higher animals. A dog, a bird, or a fish, for example, undoubtedly represents each a pure 'individual.' If the origin and development of such a being be traced, we find, firstly, that it is produced by true or sexual reproduction; and secondly, that it represents *the total result of the development of a single ovum or egg.* Hence we may accept the latter expression as the definition of the true zoological 'individual.'

Does the entire zoophyte or each of its included members, then, correspond to the higher animal? is a question that can now be readily answered. The zoophyte, as we have noted, is originally produced from a single egg, which develops a primary polypite, and gives rise by budding to the colony. And as the zoophyte with its many included animals thus really represents the development of a single egg, the entire colony is the zoological 'individual;' whilst each of its included members is named a *zoöid.* This individual differs from the bird or fish, in that it is compound in its nature; and we further observe that the numerous organisms of the colony are produced by the asexual process of budding. So that the presence of numerous 'zoöids' indicates the operation either of *fission* or *gemmation;* the true 'individual' of which they form part, however, originating from an egg. It may sometimes be difficult or even impossible to form any conception of the exact extent of the zoological individual. The single hydra, for example, represents an individual, because it originates from an egg; and so long as it does not produce others by budding, corresponds exactly to the fish or higher animal. But, when the hydra produces buds it imitates its compound neighbours, and can no longer be considered to represent a typical 'individual;' since these buds, although detached from the parent, are still to be regarded as true zoöids, and as forming part of the development of the single egg from which the parent-hydra was developed.

28. **ALTERNATION OF GENERATIONS.**—A second feature

of interest exhibited by the consideration of the zoophyte's life-history is found in the complicated phenomena of reproduction exemplified by many members of the class. These phenomena, as we have noted, include the production of a *medusa* or 'jelly-fish' bud, from the eggs of which, in turn, the zoophyte-race is again developed. To this process the name of *alternation of generations* was formerly applied; for the reason that one race or generation of animals was believed to possess the power, strangely enough, of reproducing another and different race or generation; and because the products of generation exhibited a regular alternation in their occurrence. Thus the zoophyte was seen to give origin to a medusa; then the medusa produced a generation of zoophytes; and the latter again developed medusæ; one generation thus alternating with the other. Or to mention the comparison used by one of the discoverers of the phenomena, 'the offspring in each case are unlike the parent, but always resemble their grand-parents.' We now know that the name 'alternation of generations' was founded on a mistaken idea of the process it was intended to describe. A close examination of the relations of the medusa and the zoophyte at once shews that there are not two distinct animals or generations concerned in the process of reproduction. The medusa, unlike the zoophyte as it may be, is merely its reproductive bud or zoöid, which, instead of being permanently attached to the zoophyte, and maturing its reproductive elements whilst so attached—as in the 'sea-firs'—is set free from its parent-branch, and nourishes itself apart from the organism which gave it birth. The medusa-bud cannot therefore be regarded as a distinct or 'individual' animal, since it was produced by a process of budding like its neighbour zoöids. Its energies are devoted to the production of true eggs, from each of which a zoophyte grows by a similar process of budding. Thus *alternation of generations*, or *metagenesis*, as the phenomena are now more appropriately named, merely represents a highly specialised process of reproduction. It is not permissible or correct to say that any 'generations' alternate in supposed mutual

reproduction; since there is really but one individual animal—the zoophyte—concerned in the whole process. If any alternation takes place, it is one of a process of gemmation or budding, producing the medusa, with one of true sexual reproduction, whereby the latter form produces new zoophyte 'individuals.'

CHAPTER IV.

THE SEA-ANEMONE AND ITS LIFE-HISTORY.

29. The hydra has been already noted to represent the group *Hydrozoa*—the first and lowest of the two classes into which the sub-kingdom *Cœlenterata* is divided. The second and higher class is represented in quite as typical a manner by the sea-anemones or *Actiniæ* of our coasts. This latter division bears the name of *Actinozoa*, and an examination of the sea-anemone will afford opportunity not only for gaining an idea of the structure of all the organisms included in its class, but also for comparing the details of that structure with the somewhat simpler organisation of the hydra and its neighbours.

External Appearance of the Sea-anemone.—With the appearance of the commoner species of Actiniæ or Sea-anemones, every visitor to the sea-side, or to the large aquaria now established in various towns, must be familiar. Viewed externally, a sea-anemone is not unlike a hydra, in so far at least as its general form and appearance is concerned. Each organism (fig. 11, A) consists of a cylindrical body, attached by one extremity to some fixed object, and possessing at the other extremity a mouth surrounded by tentacles. Indeed, if we suppose a hydra to become greatly enlarged; to have its body compressed and shortened; and to develop a greater number of tentacles surrounding its mouth, we may theoretically convert the hydra-body into that of a sea-anemone. Poets have often alluded to the flower-like aspect of the sea-anemones,

as they appear in their expanded state, coloured with various tints and hues, in the marine grottoes and rock-pools of our coasts. However flower-like they may appear, the anemones are highly sensitive to touch; for if the

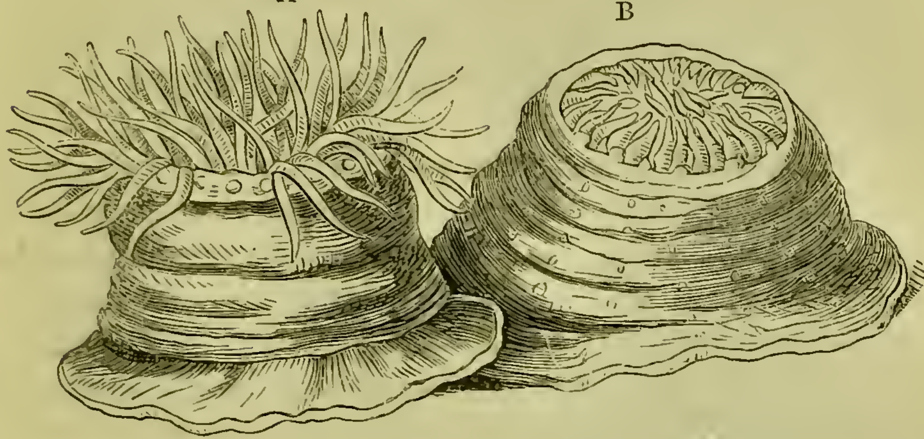

Fig. 11.—Actiniæ: *Actinia mesembryanthemum*, the 'Beadlet,' or Common Sea-anemone; A, expanded; and B, contracted.

tentacles of one of these organisms be even lightly touched, they will be seen to be quickly retracted within the mouth; and after ejecting the water contained within the body-cavity, the animal in a short space of time will be found to present the appearance of a conical mass (fig. 11, B), utterly unlike the graceful being represented by its expanded state. But if left undisturbed, the animal soon recovers from its irritation, and slowly assumes its wonted flower-like aspect. Thus, before the *animal* nature of the anemones and their allies had been ascertained, it is hardly to be accounted wonderful that the older naturalists regarded these organisms as sensitive marine flowers, whose petals, like the leaves of the 'sensitive plant,' shrank and closed on being irritated or disturbed.

Viewed externally, then, the sea-anemone presents for examination a cylindrical body or *column*, as it is named. Its attached extremity is known as the *base;* and its oral or mouth-region as the *disc*. Like the hydra, the sea-anemone is not permanently rooted, but, as may be observed in marine aquaria, has the power of moving slowly about

by the contraction of the muscular base. The tentacles in the sea-anemone are much more numerous than in the hydra, and are disposed in alternate rows around the outer edge of the disc, so that a vacant space named the *peristome* or *peristomial space* (fig. 13, *d*) exists between the mouth and the tentacles. The mouth itself usually appears as an opening of elliptical shape, and may be bounded in some cases by a raised margin constituting a kind of 'lip.'

30. **STRUCTURE OF ANEMONE.**—When a vertical section is made through the body of a sea-anemone, as represented in figs. 12 and 13, the general structure of the animal may be readily appreciated. The body-wall is seen to be composed, as in hydra, of ectoderm, *ec*, and endoderm, *en*, and to inclose a body-cavity, or *somatic* cavity, as it is also named. But a marked difference is also perceptible from the structure of the hydra, in that we find a sac or bag, *s*, into which the mouth opens, depending within the body-cavity, or *enterocœle.* This sac, in turn, opens below into the body-cavity (fig. 12, *a*, *a*) of the anemone,

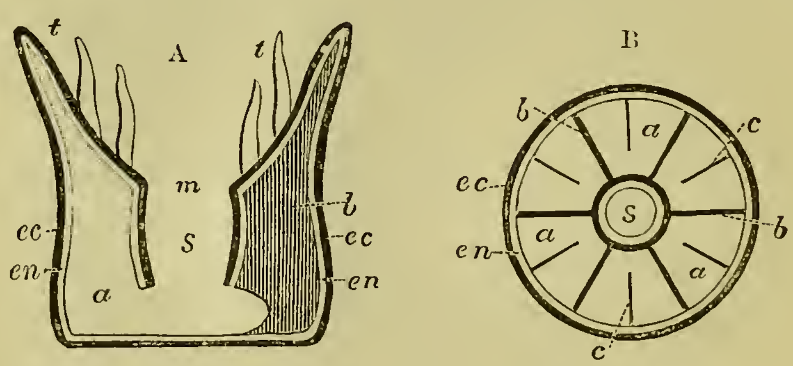

Fig. 12.—Morphology of Sea-Anemone: A, diagrammatic vertical section of sea-anemone: *a*, body-cavity exhibited on left side, and *b*, a primary mesentery dividing the body-cavity on the right; *ec*, ectoderm; *en*, endoderm; *m*, mouth; *s*, stomach-sac, formed of ectoderm and endoderm; *t*, *t*, tentacles. B, transverse section of sea-anemone; *c*, *c*, secondary mesenteries; other references as in fig. A.

and may therefore be compared to a pocket with the bottom cut out. The sac, which is the *stomach* of the animal, does not hang loosely within the body-cavity, but is kept in place, and connected to the walls of the body by a series of

vertical flattened plates or partitions. These plates, named *mesenteries* (fig. 12, B, *b*, *b*), therefore divide the body-cavity, or space between the stomach-sac and body-walls, into a number of spaces named *intermesenteric chambers*, *a*, *a*, which communicate freely below with one another, and also with the lower opening of the stomach.

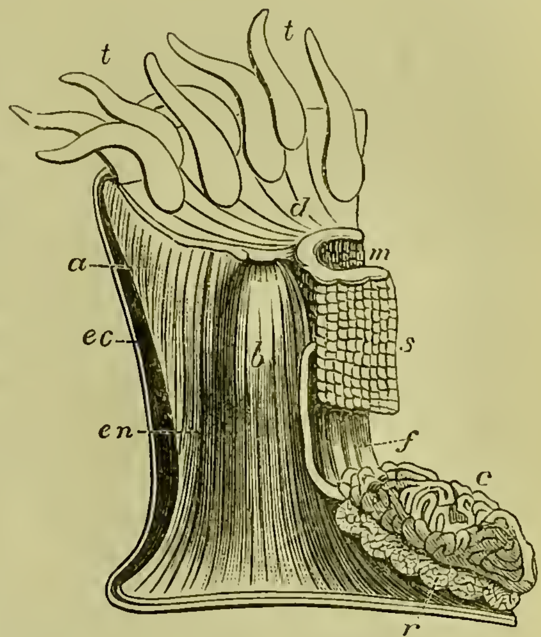

Fig. 13.—Dissection of Sea-anemone: *a*, muscular layer of body-wall; *b*, mesentery; *c*, craspedum; *d*, peristome; *ec*, ectoderm; *en*, endoderm; *f*, body-cavity; *m*, mouth; *r*, reproductive organs; *s*, stomach-sac; *t*, *t*, tentacles.

Mesenteries, &c.—A transverse or cross-section of the sea-anemone's body (fig. 12, B) will serve to render plain the arrangement thus described. Thus in cross-section the body somewhat resembles a wheel in appearance, and is seen in reality to consist of two tubes, one tube being contained within the other. The outer tube or rim of the wheel, *ec*, *en*, represents the walls of the body, and the inner tube or nave, the stomach-sac, *s*; whilst the radiating partitions, *b*, *b*, corresponding to the spokes of the wheel, represent the mesenteries attaching the stomach to the body-wall. The mesenteries in the anemone, however, are seen to vary in size and in their relations to the stomach-sac. They are arranged in definite cycles, and bear a constant relation in number to the tentacles. Those mesenteries, *b*, *b*, which pass from the stomach-sac to the body-wall, and which therefore divide the intervening body-cavity completely into chambers, are named *primary* mesenteries. These are the first-formed and longest mesenteries. They are attached to the stomach throughout its length; and as the stomach is much shorter than the body-cavity, the primary mesenteries each become free from the stomach

below. Each mesentery (fig. 12, A, *b*) is then seen to curve outwards or towards the body-wall, and then gradually downwards and inwards, so that its lower edge finally becomes attached to the centre of the base of the body. Other and shorter mesenteries (fig. 12, B, *c*, *c*) are also developed between the primary layers. These are named *secondary* mesenteries; and although, like the primary ones, they spring from the body-wall, they do not reach the stomach, *s*, and therefore bear no part in the attachment of the latter organ to the body. The secondary mesenteries serve, of course, to further and imperfectly divide the chambers or spaces between the primary mesenteries. And others still narrower than the secondary mesenteries, and named *tertiary* ones, may also be found to originate from the wall of the body. A well-defined law of growth appears to regulate the growth of these mesenteries. In the anemones and their near allies, the tentacles and mesenteries are developed in multiples of 5 or 6. Thus, at first, six primary mesenteries are developed. When secondary mesenteries are produced, they appear between the primary or already formed ones; and the tertiary mesenteries in their turn are developed between those previously existing. The manner of growth of these structures might be illustrated by making A stand for primary, B for secondary, and *c* for tertiary mesenteries. The growth of three series of mesenteries may therefore be thus represented: A*c*B*c*A*c*B*c*A, &c.

31. **Tentacles, &c.**—The tentacles of the anemone (fig. 11, A; figs. 12 and 13, *t*, *t*) are found to be simple hollow processes of the body-cavity, perforated at their extremities, and communicating internally with the intermesenteric chambers (fig. 12, A, *a*). As the tentacles correspond with the mesenteries in their number, they are found at first to number only five or six. But they rapidly increase in number by a process of growth and order similar to that observed in the increase of the mesenteries, and are usually disposed in two or more alternating and concentric series. The common species of anemones may possess two hundred or more of these structures. It may lastly be noted, that the external examination of the anemone reveals the presence

of a series of blue or white spots around the margin of the disc (fig. 11, A). These spots consist of little masses of pigment or colouring-matter, to which the function of sight has been attributed. And observers have also described various warty processes of the outer layer of the body as existing in many anemones in the neighbourhood of the mouth and elsewhere; the function of touch being assigned to these processes.

32. **HISTOLOGY OF ANEMONE.**—The detailed description of the internal anatomy of the sea-anemone may be prefaced by an account of its histological or microscopic structure. Its Cœlenterate character is evinced, as already remarked, by the fact that the tissues of its body are divisible into an *ectoderm* and *endoderm* (figs. 12 and 13, *ec* and *en*). But in conformity with the defined contractile movements of the tentacles and body when irritated or disturbed, we are prepared to find an advance upon the comparatively simple microscopic structure of the hydra. The ectoderm especially, and also the endoderm, exhibit a complicated structure in their subdivision and development into several distinct tissues or layers, of which *muscular* tissue, or that whereby the movements of the animal are effected, is perhaps the most important. The ectoderm (fig. 13, *ec*), as seen in the body-wall, thus consists of two layers. The outer layer, *ecderon*, or *epidermis*, as it is named, forming the outermost layer of the body, is composed of *epithelial* cells, containing but few nuclei; and of so-called *gland and pigment cells* and thread-cells. The pigment-cells secrete the colouring matters which give to the anemones their beautiful and varied hues. This layer grows from within outwards. The *enderon* or inner layer of the ectoderm is composed of a tissue, which, under the microscope, resembles striated muscular tissue (fig. 13, *a*). This layer grows from without inwards, and constitutes one of the muscular layers of the body. The endoderm or inner tissue, *en*, consists of two muscular layers, some connective tissue, and an inner lining of delicate ciliated epithelial cells. The outer of the two muscular layers of the endoderm is made up of *circular*, and the inner and deeper layer of *longitudinal* fibres. The

layer of circular muscular fibres is especially well developed around the mouth and in the tentacles ; the functions of this layer in these situations being to close the oral aperture, and to contract the tentacles ; whilst the longitudinal fibres compress the body from above downwards. The tentacles themselves are formed of ectoderm and endoderm, and exhibit essentially the same structure as the body-wall itself. It may be noted that the name *mesoderm* is frequently applied to the muscular layer (fig. 13, *a*) of the sea-anemone, from its intermediate position with reference to the other two layers. The correspondence of the muscular layers with the mesoderm of the hydra will be readily traced.

The mesenteries (figs. 12 and 13, *b*) being simply internal processes of the body-wall, correspond with the latter in their structure. A thin layer of the endoderm invests each side of each mesentery, and covers the reproductive organs (fig. 13, *r*), which, as will be presently noted, are developed on the surfaces of the mesenteries. Four muscles, two for each surface, are developed in connection with each of the mesenteries, so that these structures participate in the general contraction of the body ; and the stomach itself (fig. 13, *s*) also possesses a muscular layer. It is highly probable that a circular or *sphincter muscle* exists at the lower and open extremity of the stomach ; the function of this latter structure being to temporarily close the stomach, and to convert it into a pocket-like organ during the digestion of food. The stomach itself agrees in structure with the body-wall. It is composed of ectodermal and endodermal layers, only of more delicate kind than are found in the body-wall. Its outer surface is thrown into deep plaits or folds (fig. 13, *s*), and its inner surface or endoderm is richly furnished with the vibratile filaments named *cilia*. No pigment-cells occur in the ectodermal layer of the stomach ; but some observers have maintained that a thin layer of red or brownish cells at the upper portion of the stomach replaces the pigment-cells, and furnishes a secretion of use in the digestion of food, and supposed to be analogous to the liver-secretion or *bile*.

CILIA.—The *cilia* alluded to are microscopic filaments,

borne by the cells of many animal and plant tissues, and which exhibit inherent vibratile powers. They are seen in living tissues to be in a state of constant vibration. The closest scrutiny by the microscope fails to detect the means whereby these movements are carried on; and at present we are therefore forced to conclude that ciliary motion depends on some peculiar vital property of the protoplasm of which these delicate filaments are composed. Cilia are well seen, for example, in the gills of the mussel (see Chapter V., par. 46), or in the epithelial cells lining the human windpipe (fig. 14). They may constitute, as in many Infusorial and Wheel-animalcules (*Rotifera*), the organs of motion of animal forms. The length of each cilium in the cells of the human windpipe, for example, is about one three-thousandth of an inch; but they may measure one five-thousandth of an inch in length, or even less, in other cases.

Fig. 14.—Ciliated Cells: epithelial cells from human windpipe possessing vibratile cilia.

33. **Reproductive Organs; Craspeda, &c.**—The remaining structures to be noticed in the sea-anemone are the reproductive organs, and certain bodies named *craspeda.* The reproductive organs (fig. 13, *r*), situated on the surfaces of the mesenteries, appear in the form of reddish bands or masses contained within the delicate sac or covering formed by the union of the layers of endoderm covering each mesentery. The male and female organs are indistinguishable, save that the former produces spermatozoöids, and the latter ova or eggs. The sexes are usually contained in distinct and separate anemones; some being males and others females, as in higher animals, although there are no outward marks by which the sexes can be distinguished. These animals are therefore named *diœcious.* But in some cases, male and female reproductive organs may be contained, as in hydra, in one and the same sea-anemone; the name *monœcious* being applied in the latter case.

The endoderm covering the reproductive organs appears

to be prolonged on the edges of the mesenteries, and to give origin to certain coiled or twisted cord-like structures, richly ciliated, and named *craspeda* (fig. 13, *c*). Certain other structures of similar nature are named *acontia*, and both organs are very plentifully furnished with thread-cells. The curious fact has also been noticed that the filaments of these thread-cells can be protruded through special apertures, named *cinclides*, which exist in the body-wall of the anemone. The existence of such apertures in the body-wall may be readily demonstrated by any one who detaches an anemone from its attachment to a rock, and gently compresses its body. The water contained within the body-cavity, and usually emitted by the mouth, will be observed under pressure to escape from openings in the body-wall. These openings are the cinclides just referred to; and the animals appear to possess the power of opening and closing these apertures at will. It is possible that the cinclides may naturally emit the fluids contained within the body-cavity; and they may thus also serve as excretory openings.

34. **PHYSIOLOGY OF SEA-ANEMONE.**—The consideration of the physiology of the sea-anemone leads us firstly to notice its manner of nourishing itself, or, in other words, of providing for its sustenance and growth. The food, consisting of crabs, whelks, and other organisms which stray within reach of the tentacles, is seized by the latter organs, drawn towards the mouth, and thereby passes into the stomach-sac. The sphincter or circular muscle existing at the lower and internal opening of the stomach-sac, probably, as already remarked, closes the stomach temporarily; whilst the indigestible portions of food are rejected by the mouth. The nutritive fluids which are formed in the stomach-sac, as the result of the digestion of food, finally pass into the general body or somatic cavity, as in hydra, and are circulated throughout the intermesenteric chambers by the action of the currents created and maintained by the cilia (fig. 14) of the endoderm. Sea-water from the exterior is taken in to a greater or less extent by the mouth, and necessarily mingles with the products of digestion; the combined fluids forming a common nutritive fluid, to which

the name of *chylaqueous* or *perivisceral* fluid may be applied. Thus the tissues of the anemone are literally bathed in the nutrient fluid, which represents the 'blood' of higher animals, and which, like the latter fluid, is found to contain minute solid particles or *corpuscles*. The currents created by the cilia may be noted to perform the functions of a heart in circulating the nutritive fluid through the body; whilst a due supply of oxygen is obtained from the water taken into the body-cavity of the mouth, this latter act representing that of *respiration* or breathing in higher animals. No organs corresponding to gills, and to which the function of breathing can be attributed, are developed in the sea-anemones.

INNERVATION OF SEA-ANEMONE.—No structures known with certainty to correspond with a nervous system have been detected in the sea-anemones. Allusion has already been made to the bead-like masses of pigment (fig. 11, A) situated around the edge of the disc. These pigment spots are found on examination to contain certain structures which refract light, as well as other elements, the presence of which strongly suggests the idea that these bodies may be rudimentary eyes. It seems somewhat strange and anomalous to talk of eyes or organs of sense existing separately and dissociated from a nervous system; but as we have already remarked in the case of the *Hydra* and in the still lower *Amœba*, it is possible that nervous actions and powers may be exerted by the general tissues of the body, and apart from any distinct system of nerves. Some observers have fancied that they could detect fine filaments, related to certain cells described as nerve-cells, in the tissues of sea-

Fig. 15.—Ctenophora: *Beroë*, one of the Ctenophora or highest Actinozoa.

anemones; but admittedly such observations require confirmation. The fact that the first definite traces of a nervous system, as we examine the animal series from below upwards, appear in the higher members of the class Actinozoa, may, however, weigh in favour of the latter opinion. The allies of the sea-anemone which possess a distinct nervous system are collectively named *Ctenophora;* and are represented by certain free-swimming and oceanic organisms, such as *Beroë* (fig. 15), &c. The explanation of the shrinking of a sea-anemone when touched, and of its other symptoms of sensitiveness, depend on the recognition of the existence of a nervous property residing in the tissues generally. Indeed, the most philosophic view of a nerve that has yet been taken, is that which regards it as a specially modified line of protoplasm connecting two parts of an organism, and exciting in these parts acts or effects corresponding to the impressions made upon it. Such an idea may afford some reasonable explanation of the probable nature of the elementary nerve or sensory apparatus which exists in lower organisms.

35. **REPRODUCTION AND DEVELOPMENT.**—Reproduction in the sea-anemones may take place, as in hydra, both sexually and asexually. The asexual methods of reproduction—fission and gemmation—are not frequently observed in the more common sea-anemones. Like the hydræ, the sea-anemones may be artificially divided into two or more new parts, each of which in due time becomes a new and perfect individual. Gemmation or budding does not occur in the sea-anemones, but in certain of their nearest allies the process of budding produces a kind of social colony or collection of connected individuals. Thus the coral-polypes, which make the well-known coral substance, and which are Actinozoa nearly allied to the sea-anemones, are for the most part compound in nature, and form huge reefs by a process of continuous budding, similar to the process which occurs in zoophytes. The only reproductive process, therefore, which attains any importance in the common sea-anemone is the sexual form, by means of the fertilisation of ova or eggs.

The ova of sea-anemones are of rounded form, and are formed in the ovaries already described. They exhibit before fertilisation the structure common to all ova as figured at B, fig. 7. The spermatozoöids possess each a head or body and a vibratile tail; and the fertilisation of the eggs would appear to be effected whilst the eggs are still within the body-cavity of the parent. Here also the early stages in the development of the young may be carried out. Any one who keeps the sea-anemones in an aquarium, and attentively watches their life-history, will frequently notice very small or even minute young escaping from the mouth of the parent and attaching themselves to the side of the vessel; these young anemones exactly resembling the parent in every detail save size, and perhaps the number of tentacles and mesenteries. The egg of the sea-anemone undergoes the process of segmentation described as common to the eggs of all animals, and attains the *morula* or 'mulberry' stage of development (fig. 7, E). The blastoderm divides into its epiblast and hypoblast, and the young embryo appears as an elongated and oval body, provided with cilia on its outer surface, and named a *planula* (fig. 7, F, and fig. 16, *a*). At this stage, the embryo may escape from the parent body, and moves rapidly through the sea by means of its cilia. Soon a depression or indentation (fig. 16, *b*), representing the future mouth, appears at one extremity, and meanwhile the internal part of the embryo has been enlarged so as to form the future body-cavity (fig. 16, *c*); this stage corresponding to the *gastrula*-stage already referred to in the development of the Hydra. After the formation of the

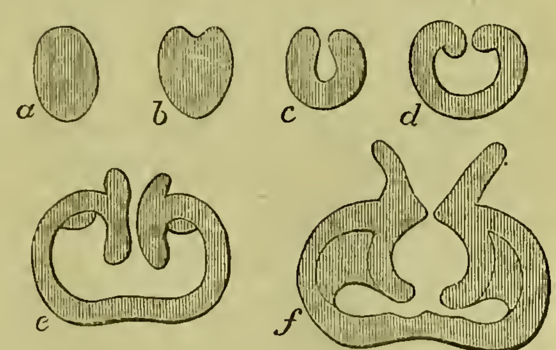

Fig. 16.—Development of the Sea-Anemone: *a*, planula; *b*, mouth beginning to be formed; *c*, formation of body-cavity; *d*, involution of body-wall to form stomach; *e*, formation of tentacles and mesenteries, and further development of stomach-sac; *f*, more advanced stage of *e*. (These drawings are semi-diagrammatic.)

mouth, a growth of the body-layer begins to be folded inwards from the mouth (fig. 16, *d*), and finally appears as the stomach-sac, *e*, *f*; this structure remaining open below, and communicating freely, as in the adult, with the general cavity of the body. The structure of the stomach-sac, thus formed, is seen to be identical with that of the body-layer from which it is developed; but it is difficult to say whether the formation of the stomach is effected by a process of invagination or inward folding of the body-layer, or merely by a simple downward growth. Small tentacles, *e*, *f*, at first numbering five or six, also begin to bud out, around the mouth; these rapidly increasing in number. The tissues of the body also undergo contemporaneous development, from the two layers of the blastoderm; thread-cells being especially developed in the outer layer or ectoderm. The primary mesenteries are at first represented by two of these structures, *e*, which appear opposite to each other, and are situated one at each side or angle of the mouth. All the mesenteries are developed from above downwards; the secondary mesenteries in due time appearing after the development of the primary ones.

36. *Sea-anemones in Aquaria—Parasitism.*—The sea-anemones may be kept in aquaria for many years, and produce numerous young when well fed and supplied with duly aërated water. One famous anemone* (*Actinia mesembryanthemum*), first possessed by Sir John Dalzell in 1828, produced 276 young in six years; this animal, known as 'Granny,' being still (1877) alive, and having occasionally produced young in large numbers. Between 1828 and 1851 'Granny' produced 344 young anemones; and in 1857, in one night, gave birth to 240 young. Not the least curious part of the history of some sea-anemones, is that afforded by the fact, that some large species inhabiting tropical seas, and measuring from one to two or even three feet in diameter, afford shelter within their body-cavities to little fishes; the latter existing as guests within their strange and otherwise voracious hosts. This instance affords an

* This anemone has been in the possession of Dr M'Bain, of Trinity, near Edinburgh, since November 1857.

example of the curious animal-association known to naturalists as *commensalism:* the anemones affording house-room to their fish-guests; whilst, however, the latter do not appear to nourish themselves at the expense of their hosts. Commensalism and other animal companionships are probably to be regarded as analogous to cases of true *parasitism*, in which one animal not only lives in or upon, but nourishes itself at the expense of its host.

ZOOLOGICAL CHARACTERS DERIVED FROM THE ANEMONE'S STRUCTURE.

37. The points in general zoology elicited by an examination of the sea-anemone, include, amongst others, an illustration of the meaning of the name *Cœlenterate* as applied to the sub-kingdom of animals in which the hydræ, sea-anemones, and their neighbours are included. The fact that the digestive system or stomach-sac freely communicates with the body-cavity, is fully exemplified by the structure of the sea-anemone, and even more typically than in the hydra; whilst the other characters of Cœlenterata, such as the development of ectoderm and endoderm, and the presence of thread-cells, are also well illustrated in the present instance.

The essential difference and distinction between the hydra-class (*Hydrozoa*) and the class (*Actinozoa*) of which the sea-anemone is the type, may also be noted. Thus all Actinozoa have a stomach-sac, specialised or separated from the body-cavity (figs. 12 and 13, *s*); whilst the Hydrozoa do not possess such a structure. Then, also, whilst the reproductive organs in Hydrozoa are mere external processes of the body-wall, those organs in Actinozoa are situated internally. We also note in the sea-anemone an illustration of the further specialisation of the digestive system and function from what was observed in hydra, in virtue of which specialisation the anemone becomes a higher animal than its fresh-water neighbour. In the hydra, and in all other Hydrozoa, the general cavity of the body serves for a digestive system; but in the sea-anemones and other

Actinozoa the food is assimilated in a specialised cavity—the stomach-sac—although that sac does not attain the condition seen in higher animals, in which the digestive system is completely shut off from the body-cavity.

Coral-polypes.—We may lastly observe the near relationship of the sea-anemones to the coral-polypes, and the increase of the latter by the process of budding, not represented in the common sea-anemone. The coral-polypes are in fact simply *Actinozoa*, exhibiting the essential structure of sea-anemones, but possessing the power—faintly imitated in forms closely allied to the common sea-anemones—of secreting from the sea-water limy or calcareous matter, which they build up in various fashions to form wondrous reef-like masses, which become in time solid and enduring parts of the earth's crust.*

CHAPTER V.

THE FRESH-WATER MUSSEL.

38. We pass in the present lesson to consider the structure and physiology of the fresh-water mussel or *Anodon*, an animal widely removed in zoological position from the cœlenterate organisms just described. Several distinct species or kinds of animals are known to the naturalist as 'fresh-water mussels.' Of these the most familiar are the species of the genus *Unio*, and the *Anodonta cygnæa*—the 'Common River,' or 'Swan Mussel,' as the latter is often named. All of these fresh-water mussels belong to one family, that of the *Unionidæ;* and the genus Unio itself, included in this group, has attracted considerable attention of other than zoological kind, from the fact that British pearls have been obtained in tolerable plenty from one species—the *Unio margaritifer*—formerly common in many Scotch rivers. The marine mussels, which exist in such numbers

* For an account of the manner in which coral reefs are formed, the reader is referred to Geikie's *Geology* (Chambers's Elementary Science Manuals), pp. 61, 62.

on the sea-coasts, belong to a nearly allied but different family, named *Mytilidæ*. The latter mussels differ in certain minor points of organisation from their fresh-water neighbours; but the bodies of both kinds, together with a host of other and allied animals—such as oysters, cockles, clam-shells, &c.—are found to be constructed on one great type or plan, for the convenient illustration of which, no better example could be selected than the fresh-water mussel. It may also be noted, as a last general feature of these animals, that along with the oysters, &c., they belong to a great class known as the *Lamellibranchiata;* this class forming one of the subdivisions of a great sub-kingdom of animals, to which the name *Mollusca* is applied. The characters of the class and sub-kingdom will be noted after the examination of the form we have selected as a typical representative.

SHELL OF THE MUSSEL.—As every one knows, the fresh-water mussel represents a group of the animal world which includes those forms we familiarly denominate 'shell-fish.' The possession of the structure known as a *shell*, therefore, constitutes a highly distinctive feature of the animal before us, and also presents an appropriate starting-point for our examination. This shell, we observe, consists in the mussel of two halves (fig. 17, s^1, s^2), or, as they are termed, *valves*, of equal size and similar shape. Hence, like all other mollusca which possess a shell consisting of *two* pieces, the mussel is named a *bivalve* mollusc. The valves of the shell, when regarded in relation to the animal which inhabits them, and when placed in their natural position, are seen to lie laterally, or side by side. One valve is therefore named the *right*, and the other the *left valve*. The way in which each valve may be distinguished, consists in the appreciation of the various surfaces of the shell. Thus the valves are seen to be connected by a kind of hinge (fig. 17, *e*) along one border or margin, which may be named the *dorsal* or upper border, whilst they open along the opposite, inferior, or *ventral* margin. One extremity of the shell is readily seen to be somewhat pointed, as compared with the broader and more rounded end. The former may be named the hinder

or *posterior*, and the latter the front or *anterior* extremity of the shell. A prominence on the outside of the shell, termed the *umbo* or 'beak,' *c*, which is not over-distinctly marked in the mussel, points to the anterior border of the shell. If, having thus determined the general configuration

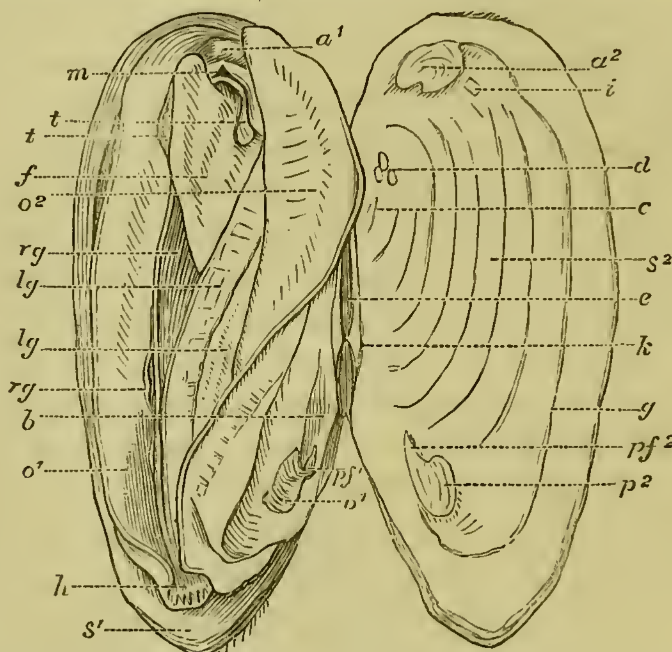

Fig. 17.—Morphology of Fresh-water Mussel (*Anodon*). (The shell has been opened, and the attachment of the adductor muscles to the left valve cut through. The animal is represented as lying within the right valve of the shell.) a^1, anterior adductor muscle; a^2, its impression on the left valve; *b*, point underneath which the organ of Bojanus lies; *c* indicates, on the internal surface of the left valve, the situation of the external *umbo* or beak; *d*, scar of some fibres of the anterior retractor muscle of foot; *e*, shell-ligament; *f*, foot; *g*, pallial line; *h*, exhalent or dorsal siphon; *i*, impression of protractor muscle of foot; *k*, one of the ridges between which the ligament of the shell, *e*, is placed; *lg*, *lg*, gills of left side; *rg*, *rg*, gills of the right side; *m*, mouth; o^1, right lobe, and o^2, left lobe of mantle, the latter turned outwards at its anterior end; p^1, posterior adductor muscle; p^2, its impression on the left valve; pf^1, posterior retractor of foot, and pf^2, its impression on left valve; s^1, right, and s^2, left valve of shell; *t*, *t*, labial palpi.

of the shell, the observer takes the shell in hand, and keeps the hinge or dorsal margin uppermost, the umbo or beak will point to the anterior border of the shell. The valve on the observer's right-hand side will be the right valve of the shell, provided the shell is held with the anterior extremity furthest from him; whilst the other and opposite valve will be the left. The valves of the shell are seen to be of an

irregularly oval shape, and the shell may be described as forming a hollow cone, the apex or umbo of which is turned to one side; the shell being thus really more developed to one side than to the other. The anterior or front half of the shell being shorter than the posterior half, the shell is named *inequilateral*. As we have remarked, however, its halves are of equal size, and hence it may be also named *equivalve*.

39. **Observation of a Living Mussel.**—A living anodon allowed to remain undisturbed in its native waters may be seen to burrow in the mud of the bottom, and to execute slow movements by aid of the foot (figs. 17 and 18, *f*), an

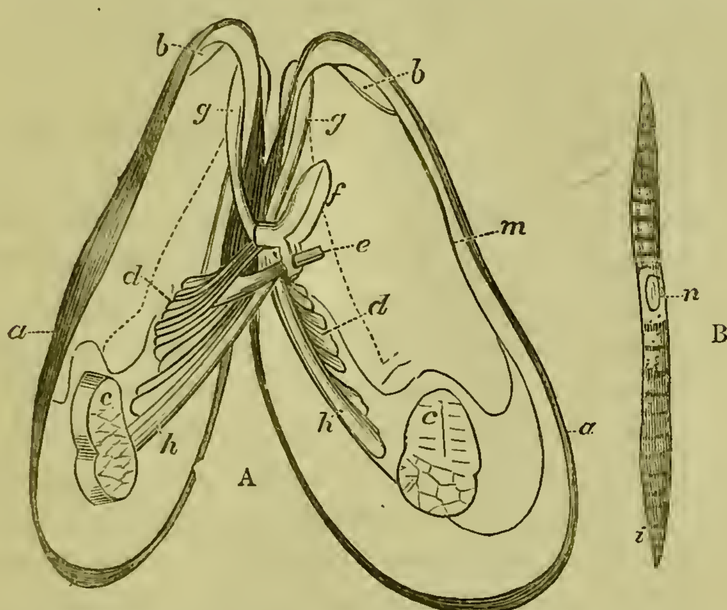

Fig. 18.—Muscles of Lamellibranchiate, A (*Modiola*): *a, a,* shell margins; *b, b,* scars of anterior adductor muscle; *c, c,* posterior adductors; *d, d,* muscles attached to *byssus* or 'beard,' *e*; *f,* foot; *g, g,* anterior retractor muscles of foot; *h, h,* posterior retractors of foot; *m,* pallial line. B, single cell of muscular fibre of anodon with nucleus, *n.*

organ to be presently described. The valves of the shell may be seen to be slightly separated along their ventral margin; and when closely examined, a thin fleshy membrane, named the *mantle* (fig. 17, o^1, o^2), can be observed to lie next each valve, whilst the foot is protruded from between the folds of the mantle. That the mussel is sensitive to impressions made upon it from without, may be learned from the quick

snap with which the valves close together when the outer surface of the shell is touched, the closure being effected by the action of certain powerful muscles named *adductors* (fig. 17, a^1, p^1). Currents of water may be shewn to pass into a living mussel by the ventral or open border, and to pass from the animal at the posterior extremity of the shell. The presence of these currents may be simply demonstrated by strewing in the water in which the mussel lives, finely divided particles of some coloured substance, such as indigo or carmine. These particles drawn in along with the currents, serve to render visible their course and direction; and this method may be employed in many other cases in which it is desirable to demonstrate the existence of defined movements in water caused by the presence of animal life.

40. **STRUCTURE OF THE SHELL.**—The investigation of the structure of the mussel leads us, firstly, to notice the shell itself, the manner of its formation and growth, and the apparatus whereby the movements connected with its opening and closure are effected. To the shell, naturalists apply the name *exoskeleton* or outer skeleton, in contradistinction to the term *endoskeleton*, applied to the internal bony framework which exists in the higher or *Vertebrate* animals only. As seen in the mussel, and in other mollusca, the shell is an inert lifeless structure, possessing no inherent powers of growth or repair. It is formed by the *mantle* or *pallium* (fig. 17, o^1, o^2), the soft, delicate membrane which lines the shell, and incloses all the organs of the animal after the fashion of a general skin or integument. The shell, notwithstanding its inert nature, is *organically* connected to the body of the mussel; in other words, the shell is attached to the animal by structures of important and vital kind. The mussel possesses no power of periodically getting rid of its shell, as is the case in the lobster, and in many other crustaceans. Externally, the shell is seen to be covered by a thin skin, named the *periostracum*, found chiefly in fresh-water shells, and which appears to protect the limy shell-substance from the wasting action of the carbonic acid gas contained in the water. At the

ventral border of each valve, the shell-substance is seen to be of softer substance and of different texture from that composing the body of the valve.

To open the shell of the mussel we have to cut across the *adductor muscles*, which, as will be presently explained, tend by their action to keep the valves in firm apposition. When this operation is carefully performed, the mantle is readily seen to lie next the shell, and to constitute two great folds or *lobes*, o^1, o^2, which are united to each other dorsally or along the upper surface, but are free below; the mantle-lobe of each valve ending at the ventral border of its valve in a somewhat thickened edge named the margin or *collar* of the mantle. The halves or lobes of the mantle adhere to the inner surface of each valve; and the thickened edge of the mantle is found to be that portion on which the growth and extension of the shell chiefly depend. The interior of the shell is seen to be lined by the lustrous substance familiar to all, and known as *nacre* or *mother-of-pearl*. This substance contributing to the thickness of the shell, is not formed by the margin of the mantle, but by its outer surface, or that lying next the interior of the valve. The iridescent and shining aspect of the interior of the shell is due to the peculiar arrangement of the delicate layers of which the nacre is composed, these layers interfering with and diffracting the rays of light. The same appearance may be produced on a sheet of dull lead, by drawing with a needle, across the lead, a great number of fine and closely set lines which interfere with the light-rays and produce iridescent hues. It is interesting to note that 'pearls' are concretions consisting of layers of nacre-substance formed by the mantle around foreign bodies, such as grains of sand, which have gained admittance to the shell, and which have found their way beneath or within the mantle.

The substance which forms the 'basis' of the shell is seen at the thin ventral edge of each valve in the soft horny-looking matter already alluded to. This substance is named the *epidermal layer*, and has a rough appearance when slightly magnified. It consists of a layer named the *pris-*

matic substance, composed in its turn of carbonate of lime deposited in vertical and elongated cavities. These cavities are themselves formed by the thickened ventral edge of the mantle-lobes. This outer portion or margin of the shell thus represents the last-formed portion, or rather that part which has been last added to the margin of the shell by the edge of the mantle. As further growth takes place, the margin of the mantle will extend beyond the prismatic layer; the latter will then be covered by the outer surface of the mantle, will receive its layer of nacre, and will thus come to resemble the older and firmer portions of the shell.

Externally the shell of anodon is observed to exhibit a greenish-brown colour. The periostracum is also formed by the mantle; and on its surface, as also on the internal surface (fig. 17) of the shell, may be traced a number of concentric ridges or lines running parallel with the shell-margin. These ridges represent the lines of growth of the shell, and, as might be expected, are more numerous and more closely apposed at the ventral margin; since, as age advances, new layers of the shell will be frequently added at this part of the structure.

SECRETION AND FORMATION OF THE SHELL.—The formation by a living being like the mussel of such a structure as the 'shell,' affords an example of the action peculiar to living tissues, and which is known under the name of *secretion.* In the performance of this action we note that certain materials—in the case of the mussel, lime and horny matter—are firstly elaborated or manufactured from the food and surrounding water, and are built up by a specialised part of the organism—the mantle—to form the shell. The exact nature of this power of appropriating matter, of further elaborating or changing that matter, and of finally forming therefrom new products and structures, cannot be thoroughly explained in the present state of our knowledge. And the possession of such a power, exhibited even by the lowest organisms, such as the *Foraminifera* (fig. 3), is therefore to be held as one of constant occurrence in the history, and as one of the most marked characteristics of living beings.

How the Shell is opened and shut.—The *umbo* or 'beak' (fig. 17, *c*) of each valve is readily noted on the dorsal or hinge-margin of the shell. The umbo is sometimes termed the *nucleus* of the shell, from the fact that it corresponds with the shell of the embryo or young animal, and forms a kind of centre around which the adult shell is gradually built up. Behind the umbones the hinge and *external ligament* (fig. 17, *e*) of the shell are situated. The latter structure is formed by a modification of the periostracum or outer horny layer of the shell. It is so named in contradistinction to the *internal* ligament, and is attached on either side to a ridge, *k*, on the dorsal margin of the valve. The internal ligament is usually described as the inner layer of the external ligament. It is found to be composed of two series of fibres which agree in structure and disposition with the layers of the true shell substance, of which the internal ligament is accordingly held to be a modification. These ligaments in greater part constitute the hinge or connection of the valves, the interlocking 'teeth,' seen in many allied molluscs, being absent in anodon. The action of the ligaments, and the share they bear in the opening of the valves, may readily be understood. The ligaments are exclusively devoted to the *opening* of the shell, and constitute the means whereby that act is effected. The fibres of the external ligament, extending from one valve to the other, are put on the stretch when the valves are closed by their appropriate adductor muscles. The fibres of the internal ligament, on the other hand, are compressed by the closure of the valves. It therefore follows that when the muscular force which closes the valves is relaxed, both ligaments, in virtue of their elasticity, will force open or divaricate the shell. Thus, when the mussel closes its shell, as when alarmed, it does so by muscular action; the act involving contraction of its adductor muscles, and a corresponding exercise of vital power. The act of opening the valves is not a vital, but simply a mechanical action, exerted through the physical properties of the shell-ligaments. An excellent example is thus presented of the economical ordering of vital action. The open condition of

the shell is, in fact, the natural state of the animal. This state is further maintained without muscular effort or exertion, the unclosure of the valves being necessary for nutrition and respiration. The act of closure, as we have seen, on the contrary, is associated with considerable muscular action; but, at the same time, it is one not often demanded by the exigencies of the animal's existence. Muscular power is thus husbanded, and undue exertion avoided by this arrangement.

41. **MUSCLES OF ANODON.**—The internal surface of the shell presents certain important markings for examination. At each extremity of the interior of the shell, and more towards the upper than the lower margin of each valve, a somewhat oval mark, a^2, p^2, may be observed. These represent the insertions of the two great *adductor muscles*, a^1, p^1, which close the shell, and which are known by the names *anterior* and *posterior* adductors, according to their respective situations. The impression of the anterior adductor, a^2, is the larger of these two markings. Some molluscs, such as the oyster, possess one adductor only; this single muscle corresponding to the posterior adductor, p^1, in anodon. In front of the impression of the latter muscle, may also be seen a mark, pf^2, corresponding to the insertion of the *posterior retractor muscles*, pf^1, of the 'foot;' whilst the *anterior retractors* of the foot are attached to the shell along with the anterior adductor muscles. The attachment of the *protractor muscles* of the foot is indicated by a scar or mark, *i*, seen at the lower border of the anterior adductor impression. A line extending along the ventral border of the interior of the shell, from one adductor muscle to the other, marks the attachment of the muscular edge or margin of the mantle to the shell, and is hence named the *pallial line*, *g*. Whilst, lastly, two faintly-marked impressions, running from the sites of the adductor muscles, converging at the umbo, and even traceable into the hollow of the latter structure, indicate the line of growth of these two muscles; each line extending further and further away from the umbo, as the muscle altered its position conformably with the growth of the shell. The disposition of the muscles

in anodon may also be illustrated by fig. 18, in which the muscular system of *Modiola*, the 'horse mussel' of the sea, is depicted. Thus the shell margin is figured at *a*, *a*, the pallial line at *m*, and the impression of the anterior and posterior adductor muscles at *b*, *b*, and *c*, *c*, respectively. The foot is shewn at *f*, and the muscles connected with the *byssus* or beard at *d*, *d*; whilst the anterior and posterior retractors of the foot, *g*, *g*, and *h*, *h*, are also depicted.

Structure of Muscle.—The nature of the muscular fibres found in anodon, and of the large muscular organ named the *foot*, may appropriately be considered in the next instance. *Muscle* is the name given to the tissue usually aggregated into distinct bundles or organs, by means of which movements in all animals, save the very lowest, are executed. Thus the amœba moves through the contractility of its protoplasm; but in hydra, and in the sea-anemone, we have noted the development of muscular fibres by a specialisation of the ordinary body-tissues. This process of specialisation attains a further stage in animals above these cœlenterates, and distinct organs named *muscles* are accordingly met with in the anodon and its neighbours. The muscles of anodon, like those of the highest animals, are found to be composed of bundles of fibres (fig. 19), each of which may be teased out into smaller and smaller fibres, until we arrive at what may be termed the

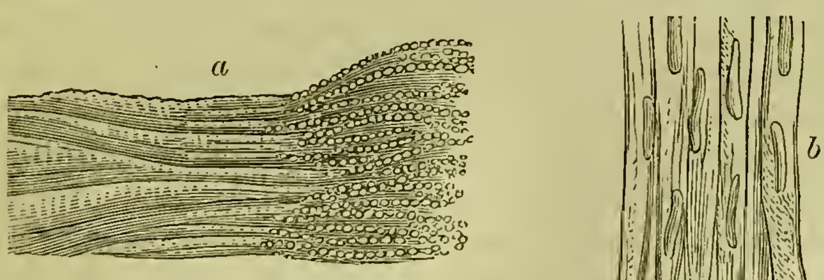

Fig. 19.—Structure of Muscle: *a*, fibres of human muscle teased out shewing transverse striping; *b*, fibres of unstriped muscle shewing nuclei.

elementary fibres or *ultimate fibrils* of the muscle. These ultimate fibres of the muscles in anodon, when examined microscopically, are seen to be made up of spindle-shaped cells (fig. 18, B) of flattened form. Each muscle-cell, when treated with acetic acid, is observed to contain a *nucleus*,

n. Around this latter structure the cell-substance exhibits a clear aspect; but the other parts of the cell contain minute granules, which are apparently arranged in cross or transverse rows. The significance of these transverse rows of granules is apparent when the nature of muscle in higher animals is studied. Thus in human muscle (fig. 19), as illustrating a high development of that tissue, two distinct varieties are to be perceived. These varieties are respectively named *striated* or *striped*, and the *non-striated* or *unstriped* muscular tissue. The fibrils of the former variety (fig. 19, *a*) are seen, when microscopically examined by transmitted light, to present alternating dark and light markings, which give them a striped or striated appearance. The darker marks are composed of minute opaque discs or square-shaped portions named *sarcous elements;* whilst the intervening lighter markings result from the presence of discs of a transparent substance, which, however, appears to be continuous with the darker portions of the fibril. Unstriped muscular fibres exhibit no such alternating arrangement of parts; each fibre containing an elongated or rod-like nucleus (fig. 19, *b*). The striated muscles are named *voluntary* from the fact of their being—with the exception of the heart—under the command of the will. The unstriped muscles are named involuntary, as they do not depend on the will for stimulation.

How Muscles act.—Returning to the muscles of anodon, we can trace in their microscopic structure an apparent correspondence to the unstriped muscle-fibres of higher forms. But their true relations are rather with the striped muscles, as indicated not only by the faintly-indicated *sarcous* elements—represented by the transverse arrangement of granules—but also from the muscles of anodon being under the command of the animal's will. The muscles of anodon act, as do those of all other animals, in virtue of the peculiar property of muscular tissue denominated *contractility.* Through the exercise of this property, muscle possesses the power of *shortening itself*, in obedience to a *stimulus*, effected through the agency of the nervous system, and of thus approximating the surfaces

between which the muscle is stretched, and to which it is attached.

Functions of the Muscles in Anodon.—The points of attachment of the chief muscles of anodon having been already indicated, their respective actions may be next noted. The function of the two *adductors* (figs. 17 and 18) is that of closing the shell by approximating its valves. The other muscles mostly belong to the *foot*. This structure (figs. 17 and 18, *f*) is found in all true mollusca. It represents a development of the ventral or lower surface of the body, and is an organ which may be much more largely developed than in anodon. In the present case, it consists of a great mass of muscles (the *intrinsic muscles* of the foot), arranged not unlike the fibres of the human tongue. The foot is also devoted to the lodgment and protection of part of the digestive and reproductive organs, and also in greater part assists the movements of the animal. The foot may thus be protruded by a triangular or fan-shaped muscle named the *protractor pedis* (fig. 17, *i*), which has its *origin* or fixed point near the anterior adductor muscle. The fibres of the muscle pass to be inserted on either side of the foot, and by their action cause its extension and protrusion. The *retractor* muscles of the foot, or those which by their action withdraw the foot, consist of an *anterior pair* (fig. 18, *g*, *g*), arising along with the anterior adductors, and sending fibres into the front portion of the foot; and of a *posterior pair* (figs. 17, *p*, f^2, and 18, *h*, *h*), springing from the front of the posterior adductors, and passing along the inner dorsal margin of the shell to the under part of the foot. Other muscular fibres named retractors are inserted into the upper part of the foot, and arise from the inner surface of each valve (fig. 17, *d*), near the umbo or beak. The last set of muscular fibres which may be noticed, is that forming the ventral margin of the mantle which is the active shell-secreting part of that structure. These fibres are attached along the pallial line (figs. 17, *g*, and 18, *m*) of the shell. They serve to protrude the edge of the mantle when the valves unclose, and otherwise assist in the disposition of that important structure, to the examination of which we may shortly proceed.

42. **THE FOOT OF ANODON.**—The foot (figs. 17 and 18, *f*) is placed in the middle line of the body, and is a yellowish organ composed of muscular fibres, and shaped not unlike a ploughshare. The apex, or point of the foot, appears to lie anteriorly and towards the lower aspect of the body. A good idea of the relations of the foot to the mantle and to the other structures of the body, may be gained from the accompanying diagram (fig. 20), representing a transverse section of the anodon. The foot, *f*, is there seen to be situated in the middle line of the body; the mantle-lobes, *m*, *m*, lie external to the other structures; whilst the gills, g^1, g^2, exist between the mantle and foot. The general plan on which the internal organisation of the anodon's body is constructed, may be readily conceived if we compare the animal to a book held by its back. The back of the book corresponds to the hinge-line of the shell-valves, which latter are represented by the covers of the book. The fly-leaves of the book will represent the mantle lobes; the second and third leaves of the book on either side will correspond to the two pairs of gills; whilst the great mass of the book lying internal to the second and third leaves, will in a rough way represent the internal organs and foot. The foot may exist in a more rudimentary condition than in anodon. It is of very small size in the oyster; and in the marine mussels, as well as in some fresh-water forms (*Dreissena*), the foot secretes strong silky threads, collectively forming the *byssus*,

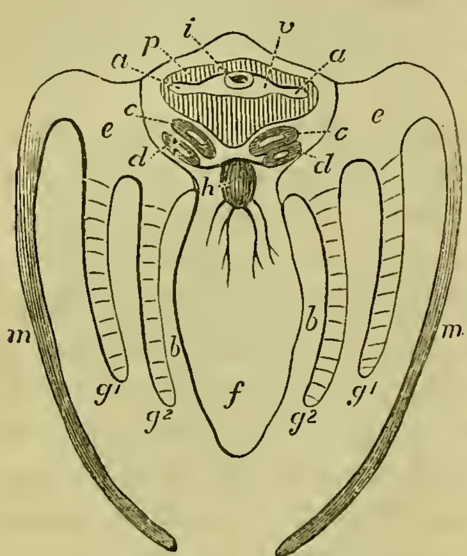

Fig. 20.—Diagrammatic Transverse Section of Anodon: *a*, *a*, auricles of heart; *b*, *b*, indicate the lower or branchial chamber of mantle containing the foot, *f*, and gills, g^1 and g^2; *c*, *c*, pleural sac, and *d*, *d*, glandular part of organ of Bojanus; *e*, *e*, indicate the cloacal or anal chamber of mantle; *h*, great venous sinus; *i*, intestine piercing ventricle, *v*, of heart; *m*, *m*, mantle lobes; *p*, pericardium.

or beard (fig. 18, *c*), by means of which the animal attaches its shell to fixed objects.

43. **THE MANTLE.**—The *pallium* or *mantle* (fig. 17, o^1, o^2), as we have seen, lines the shell; its lobes or halves being united along the dorsal or hinge-margin of the shell, but being free and separate along the ventral border, and at the anterior, and in greater part at the posterior, borders of the shell also. The mantle is a semi-transparent membrane, thickest at its ventral border, where it develops a few muscular fibres and is attached along the *pallial line*, *g*, of the shell. The microscopic examination of the mantle shews that the internal surface, or that next the viscera of the animal, is furnished with epithelial cells, possessing *cilia* (fig. 14) similar to those described as occurring in the sea-anemone. The function of these cilia is that of promoting a free circulation of the fluids contained in the interior of the shell. The surface of the mantle lying next the shell is not provided with cilia; and this latter surface, composed of cylindrical cells, as already remarked, secretes the nacre or mother-of-pearl lining of the shell.

Formation of Siphons.—At the hinder part of the lower border of the mantle, its two lobes are united to each other for a short distance. Above the point of union the mantle-lobes are separate, and the opening thus formed is named the *dorsal* or *exhalent siphon* (fig. 17, *h*), or mantle-aperture. Below the point of union, the halves of the mantle are free continuously to the anterior extremity of the shell; and the most posterior part of this larger opening produced by the separation of the mantle-lobes, is named the *ventral* or *inhalent siphon*, or mantle-aperture. The edges of these apertures are fringed with protective *cirrhi*, or hair-like processes.

Pallial and Anal Chambers.—The mantle-lobes are attached at the sides to the dorsal margins of the laminæ or plates of the outer gills (fig. 20, g^1). Behind the foot, the inner plates of the gill of each side unite for about half their posterior extent to form a partition which separates the body-space into two divisions or chambers. The lower and larger of these chambers is named the *branchial*

or *pallial chamber* (figs. 20, *b*, and 21, *o*), and contains the gills, foot, and bulk of the viscera. The upper or dorsal space is termed the *anal* or *cloacal* chamber (figs. 20, *e*, and 21, *e*), the latter being of small size. The larger and lower or ventral opening of the mantle leads into the branchial chamber; whilst the dorsal opening (fig. 17, *h*) leads from the anal chamber. These openings in many mollusca are drawn out to form long siphons or tubes; and, as will be presently explained, this disposition of the mantle-lobes and gills is connected with the supply of water to the latter organs for the performance of the respiratory or breathing function.

44. **DIGESTIVE SYSTEM OF MUSSEL.**—The *digestive* system of the mussel, or that by means of which the food is converted into nutritive material, forms the first defined system of internal organs which may be examined. As in higher animals, and in all lower forms in which a perfectly specialised digestive tract exists, this system begins at the *mouth* and ends in the *anus* or *vent*. The mouth (figs. 17 and 21, *m*) in the anodon is readily found,

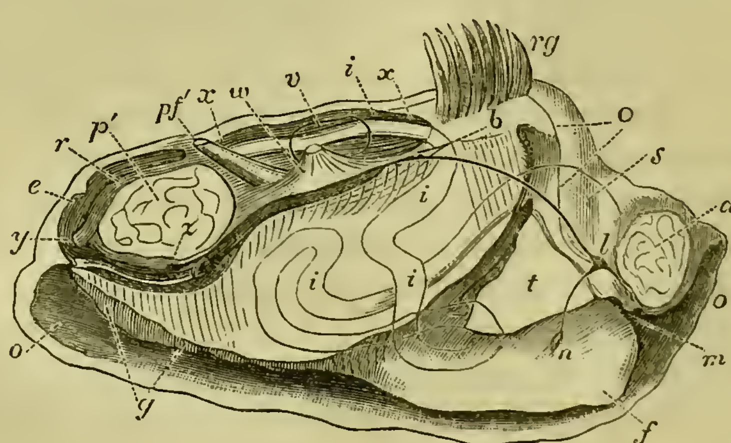

Fig. 21.—Diagram of the Structure of Anodon. (The right half of the mantle has been removed.) *e*, anal chamber; *i*, *i*, *i*, intestine; *o*, *o*, mantle, the lower letter pointing to branchial chamber; *r*, rectum; *s*, stomach; *v*, ventricle; *w*, one of the auricles of heart; *x*, *x*, pericardium; *y*, anus; *z*, branchial; *l*, cephalic; and *n*, pedal ganglia. (Other references as in fig. 17.)

and exists just below and somewhat behind the anterior adductor muscle. The anus opens above the posterior

adductor muscle, p^1, so that the digestive tract may be said to be included in the space between the adductors. The mouth, as in all lamellibranchiate mollusca, possesses no apparatus corresponding to the teeth or jaws of other animals. Hence it may be surmised that the food of the mussel consists of minute organisms and small particles of matter which require no trituration. These nutritive matters are drawn into the mantle-cavity by the currents of water used in breathing, and are thus carried into the mouth. The mouth-opening is protected by four soft triangular or leaf-like tentacles named the *labial palpi* (figs. 17 and 21, *t*, *t*), which exist two on either side. These palpi are situated in front of the gills, and on the anterior aspect of the foot. The palp of each side unites with its fellow of the opposite side, and borders or lips are thus formed around the mouth. The latter opening leads into a throat or *gullet*, which passes to the lower side of the anterior adductor (fig. 21, a^1) ; and the gullet in turn ends in the *stomach*, *s*, which opens on its right side into a pocket-like sac or *cæcum*, within which a peculiar transparent rod-like body named the *crystalline style* is contained. The function of this latter body is unknown ; but it appears to attain its greatest size after winter. From the left side of the stomach the digestive system is continued in the form of a tube named the *intestine*, *i*, *i*, *i*; and as the latter takes its first turn towards the foot and the nerve-mass therein contained, it is said to possess a *neural flexure*. The intestine is coiled upon itself in a somewhat complicated manner. It is intimately related to the mass of the foot (fig. 21), and finally terminates by a short straight portion, the *rectum* (fig. 21, *r*), which pierces the heart, *v*, and passes over the posterior adductor muscle, p^1, to end in an anus, *y*, situated on a little projection in the upper portion of the cloacal chamber (fig. 20, *e*).

Such is the course of the alimentary tube or tract considered by itself. The digestive system in animal forms, however, usually includes certain supplementary structures or glands, such as a *liver*, *salivary glands*, and allied structures. The liver in anodon is a spongy mass of brownish colour,

intimately connected to the stomach. Its function is to secrete *bile*—a fluid of use in the digestion of food; this fluid passing into the stomach by several ducts. The liver of the mussel is composed of numerous branched and pocket-like sacs or tubes (fig. 22, A, *a*), lined by epithelial cells, *b*, which manufacture the bile. No salivary glands exist in the mussel or any member of its class; and neither is any gland representing the *pancreas* or 'sweetbread' of higher animals developed.

45. **BLOOD AND NUTRITION OF ANODON.**—Within the digestive system, the nutrient matters contained in the food are, through the agency of vital and chemical actions, separated out from the unnutritious materials, and elaborated to form a fluid—the blood—adapted for nourishing the

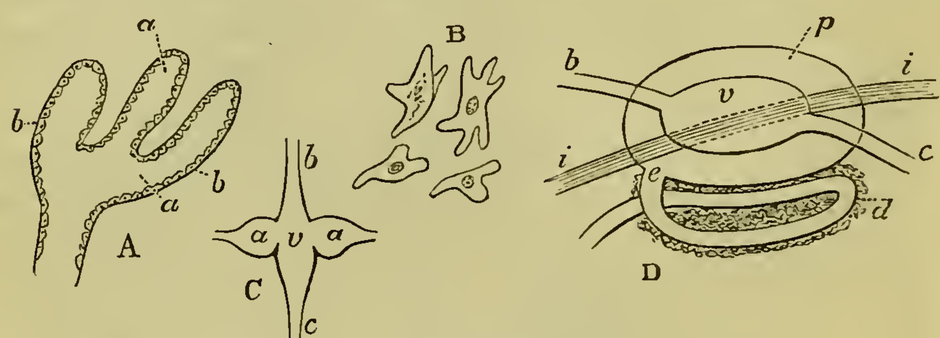

Fig. 22.—Viscera of Mussel: A, diagram of minute structure of liver, shewing *a, a,* the cæcal sacs of the liver, lined by cells, *b, b,* secreting bile. B, blood-corpuscles of anodon, largely magnified, shewing amœbiform processes. C, diagram of heart; *a, a,* auricles, opening into ventricle, *v*; *b*, anterior, and *c*, posterior aorta. D, relation of pericardium and organ of Bojanus: the pericardium, *p*, containing heart, *v*, from which the aortæ, *b* and *c*, originate, is pierced by the intestine, *i, i,* and opens into the glandular sac, *d*, of the organ of Bojanus, by an aperture, *e*.

tissues of the body. The nutritive fluid thus formed within the digestive canal of the mussel, passes through the walls of that canal, and mixes with the blood contained in the neighbouring blood-vessels. In Vertebrate animals a special set of vessels named *absorbents* is developed, for the purpose of conveying the matters elaborated from the food to the current of the blood-system. The blood, in either case, is thus periodically renewed and invigorated by the reception of fresh material derived from the digestion of food.

The blood of the mussel is a clear fluid, which on microscopic investigation is seen to contain numerous small colourless bodies (fig. 22, B) named *blood-corpuscles*. These corpuscles occur in the blood of almost all animals. They consist of minute masses of protoplasm, those of the mussel exhibiting amœboid movements.

HEART OF ANODON.—That the blood may perfectly nourish each part of the body, it requires to be circulated through the various organs and tissues. This function is performed by the *heart* and *blood-vessels*; the former propelling, and the latter conveying the blood through the system. The heart lies above and behind the liver in the dorsal or back-region of the mussel, and beneath the line of union of the mantle-lobes. It is inclosed in a sac named the *pericardium*, through the thin walls of which the heart may be seen pulsating in a living mussel. The heart itself is a muscular organ consisting of a large *ventricle* (fig. 22, C, *v*) or middle chamber, and of two smaller triangular side-chambers, named *auricles*, *a*, *a*. The intestine appears to divide the ventricle (fig. 22, D, *i*, *v*), and runs, as already noted, through the middle of this chamber. The auricles communicate with the ventricle; and the aperture by which each auricle communicates with the larger chamber is provided with a little fold of its lining membrane, which acts as a valve, and prevents the blood flowing back into the auricle when the ventricle contracts. From the front extremity of the ventricle a large blood-vessel (*anterior aorta*, fig. 22, C, D, *b*) arises, and another vessel (the *posterior aorta*, *c*) originates from its posterior end. The heart, by means of its muscular contractions, therefore acts as a kind of force-pump in distributing blood through the body.

ORGAN OF BOJANUS.—Before considering the circulation of the blood in the mussel, it is necessary to notice a structure named the *Organ of Bojanus*, after its discoverer, and also to consider how the process of respiration or breathing is effected. This organ (fig. 23) lies under the pericardium (fig. 17, *b*), and is composed of two halves (fig. 23, A), separated by a large vein—the great *vena cava* or *venous*

sinus, *v*, as it is termed. Each half of the organ of Bojanus consists of a transparent upper sac, named the *pleural sac* (fig. 23, A, B, *a*, *a*), or *non-glandular portion;* and of a brownish lower sac with plaited walls, and known as the *glandular sac* or *portion*, B, *e*, of this structure. Each upper half or pleural sac opens in front into the branchial chamber of the mantle by a distinct opening, *c*, *c*, placed close to the point where the inner gill is attached to the foot; and behind, it communicates with

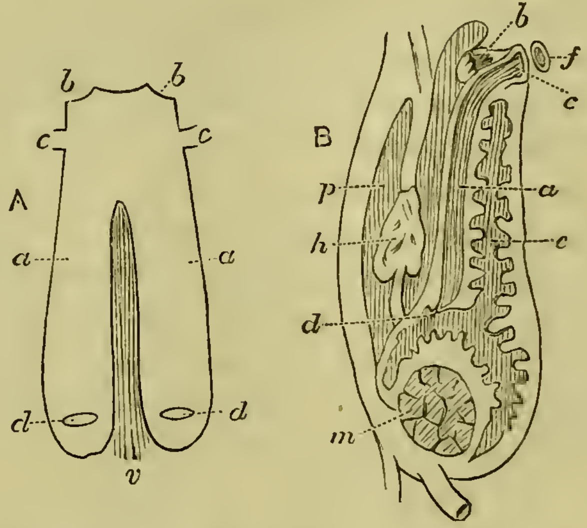

Fig. 23.—Organ of Bojanus: A, diagrammatic plan of the organ, shewing halves of pleural sac, *a*, *a*; the openings, *b*, *b*, by which the glandular sac communicates with the pericardium; those, *c*, *c*, by which the pleural sac opens into the branchial chamber; the openings of the pleural into the glandular sac, *d*, *d*; and the great venous sinus, *v*. B, section of organ of Bojanus (semi-diagrammatic), the references as in fig. A, and in addition *e*, glandular portion; *f*, generative opening; *h*, ventricle of heart; *m*, posterior adductor; *p*, pericardium.

the glandular portion of its own side by a larger slit or opening, *d*, *d*. The glandular portions of the organ also open into the pericardium, each by an aperture lying on the front portion of the floor of the heart-sac (figs. 22, D, *e*; and 23, *b*, *b*). The minute structure of the glandular portions of the organ of Bojanus shews that the folds of these sacs are lined with nucleated cells, which perform the work of excretion carried on by this structure.

46. **RESPIRATION OF MUSSEL**—*Structure of Gills.*—In the

mussel, we find that respiration, or breathing, or the function of purifying the blood by subjecting it to the action of *oxygen gas*, is performed, as in all truly aquatic animals, by means of *branchiæ* or *gills* (fig. 17, *rg*, *lg*). The position of these organs, numbering two on each side of the body (fig. 20, g^1, g^2), has been already described. They are situated within the mantle, and may be regarded as modifications of the latter structure. Each gill consists of two flat *laminæ* or leaves (fig. 24, B), united along the lower and free edge of the gill, *d*, but separate at the upper and attached margin of the organ, *a*, *a*. The united laminæ or leaves of each gill inclose a space between them. This space, *f*, *f*, is found to communicate with the cloacal or anal chamber of the mantle; and is divided crosswise by a number of bars or partitions, *e*, *e*. The outer surface of each gill is composed of vertical bars (fig. 24, A), running parallel with each other, and strengthened by short rods of chitinous or horny material; whilst internally each gill-surface exhibits a richly ciliated network of blood-vessels amidst which large apertures (fig. 24, A) can be discerned. The blood-vessels bringing impure or venous blood to be purified, are distributed on the internal surface of the gill; whilst those carrying pure blood away from the gills to the

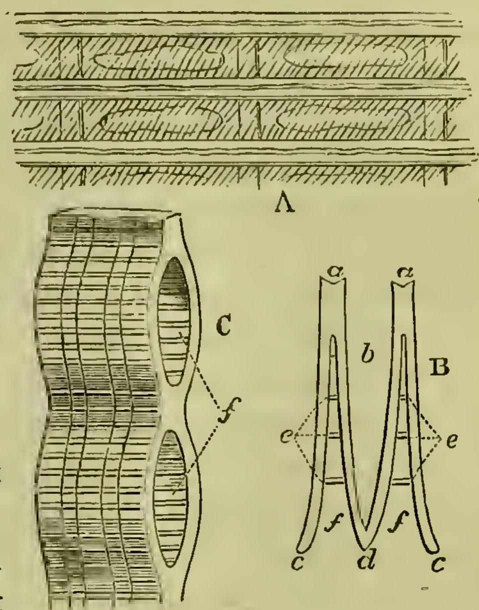

Fig. 24.—Gills of Mussel: A, layers or laminæ of gills highly magnified, shewing the apertures fringed with cilia in the meshes of the vascular network. B, ideal transverse section of the two gills of one side; *a*, *a*, points of attachment of gills above; *b*, space between the adjoining laminæ of the gills; *c*, *c*, free layer of each gill; *d*, inferior point of union between the gills; *e*, *e*, cross-bars connecting the laminæ or folds of the gills; *f*, *f*, spaces between the inner folds of gills which communicate with the anal chamber of mantle. C, section of gill-plates shewing the chambers formed by the united folds or laminæ.

heart exist on the outer aspect of these organs. The two sets of blood-vessels meet in the meshwork in the internal surface of the gills, which latter may therefore be described as consisting essentially of a network of minute blood-vessels, provided with vibratile cilia. Within these vessels the impure blood receives its oxygen from the currents of pure water, which are continually being drawn into the branchial chamber of the mantle by the cilia of the latter structure; and which are further circulated through the gills themselves, by means of the cilia with which their surfaces are so plentifully provided. The cilia of the gills (fig. 24, A) vibrate or work so as to propel the currents of water from the outer to the inner surface of these organs; and water inhaled by the branchial aperture of the mantle is thus driven through the gills towards the cloacal chamber, from which it is ejected by the dorsal siphon or upper aperture of the mantle (par. 43).

CIRCULATION IN THE MUSSEL.—The course of the circulation or blood-current in the mussel may now be traced. Pure blood is returned to the auricles of the heart from the gills, and is sent by the contraction of the auricles into the ventricle. The ventricle contracts in a wave-like or peristaltic manner, and forces the blood it contains through the two aortæ or chief blood-vessels (fig. 22, C, D), already mentioned as originating from its extremities. These great blood-vessels, when traced out to their termination, are found to divide and subdivide as they pass into the body, and by means of their branches furnish a supply of blood to every part of the organism. The blood-vessels appear to end in lesser channels which may be named *capillaries*, but it is doubtful if these capillaries are bounded by distinct walls. Many observers suppose them to be merely spaces existing between the tissues and organs of the body, through which the blood slowly circulates.

EXCRETION IN ANODON.—Having performed its nutritive function, the blood becomes impure by the absorption of carbonic acid gas, and of other matters which represent the waste matters of the body. Life and vital acts are

everywhere associated with waste. Just as a machine is subject to wear and tear, so the living body, in the exercise of its functions, throws off a certain quantity of effete or waste matters, which being no longer of use in its economy, require to be *excreted* or eliminated from the system. The blood, after its nutritive function has been performed, acts the part of a carrier of waste matters; and transports these materials in due course to the gills and to other organs for excretion; whilst at the same time it receives a fresh supply of oxygen, and thereby becomes purified and fitted for re-circulation through the body. The capillary blood-channels are accordingly found to be continued into larger vessels named *veins*. These latter blood-vessels end in the large vein named the *vena cava* (figs. 20, *h*, and 23, *v*); this vessel conveying the venous blood through the organ of Bojanus on its way to the gills. The function of the organ of Bojanus is therefore seen to correspond in its essential nature with that of the gills, in that it serves to excrete waste (nitrogenous) matters from the venous blood, and thus comes to resemble the *kidneys* of higher animals. The waste matters excreted by this organ pass outwards into the branchial chamber through the aperture already described as existing in the non-glandular part of the organ, and opening at the base of the inner gill. The opinion that the organ of Bojanus represents the kidneys, is supported by the fact that concretions of *uric acid* are occasionally found in its substance. The pericardium or heart-sac (figs. 20 and 23, B, *p*) also bears a share in the work of excretion. This sac communicates with the exterior or mantle-cavity, through the organ of Bojanus, as depicted in fig. 22, D, and also receives some of the venous blood from veins which open into it. The pericardium therefore contains both blood and water—the latter being received from the organ of Bojanus—and the impure blood is in this way also brought in contact with water from the exterior. The heart of the mussel, it may lastly be noted, is a purely *arterial* or *systemic* organ. In other words, its sole duty consists in circulating pure or arterial blood through the system, and it thus plays no

part, as does the heart of most higher animals, in the return of the impure or venous blood to the breathing organs.

A system of tubes is also found in the mussel to branch out within the substance of the foot. Certain pocket-like sacs attached to these tubes appear to contain the reproductive elements to be presently noticed. The tubular system of the foot opens outwardly by an aperture lying to the inner side of the external opening of the organ of Bojanus. The function of the foot-tubes appears to be that of distending the foot with water when that organ is to be protruded for locomotion.

47. **INNERVATION OF MUSSEL.**—Like the sea-anemone, the mussel evinces irritation when disturbed, and quickly closes its shell when touched. We have seen that in the anemone no nervous or sensory apparatus, whereby sensations might be received, is found to be developed. But in the mussel a well-defined nervous system is developed, and through this medium the mussel is brought into relation with the external world. The nerves comprise three pairs of nerve-masses or *ganglia*, coloured reddish-yellow, and connected together, so as to form a complicated system, by *commissures* or nerve-cords. Each pair of ganglia forms a kind of nerve-centre distributing nerves to, and regulating the sensations and actions of neighbouring organs. The *cephalic* or *cerebral* ganglia (figs. 21, *l*, and 25, *c*) exist at the sides of the mouth, and lie in the tendons of the anterior retractor muscle of the foot. The *pedal* ganglia (figs. 21, *n*, and 25, *p*) are united together, and exist in the substance of the foot; whilst the last pair of ganglia, named *branchial* or *parieto-splanchnic* (figs. 21, *z*, and 25, *b*), are also fused together, and are situated on the lower surface of the posterior adductor muscle. The chief nerves are, firstly, those (*commissural*) connecting the ganglia. Thus the ganglia on either side of the mouth are united by nerve-cords (fig. 25), whilst another nerve, *f*, passes from each cephalic ganglion to the pedal nerve-mass. Other cords, *e*, *e*, connect the cephalic with the branchial ganglia. Nerves given off from the ganglia to supply the

various organs of the body may be named *peripheral* nerves; and such nerves are distributed to the mantle-lobes, the foot-substance, the organ of hearing, and the various organs or viscera.

An examination of the minute structure of the nerves of anodon shews them to be composed of very fine fibres (fig. 25, B), which give off branches; each fibre consisting

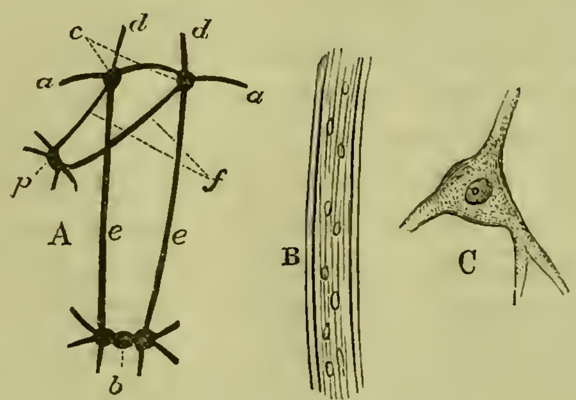

Fig. 25.—Nervous System of Mussel: A, distribution of nerves; *a, a,* nerves from cephalic ganglia, *c,* passing to mantle; *b,* branchial ganglia; *d, d,* nerves to anterior adductor muscle; *e, e,* commissural cords connecting cephalic and branchial ganglia; *f,* cords connecting cephalic and pedal ganglia, *p.* B, nerve fibre of anodon, shewing contained granules. C, ganglionic or nerve corpuscle with nucleus, and giving off branches.

of a delicate sheath, containing semi-fluid matter, but without any defined central layer. Here and there in the nerve-cords, *nerve-cells or ganglionic corpuscles* (fig. 25, C) may be seen, these latter being large nucleated cells, giving off processes, and probably acting as minor centres of innervation. Eyes are wanting in anodon, but a hearing or *auditory organ* is represented by two sacs or vesicles connected with the pedal ganglia. Each sac contains a limy particle or *otolith* suspended in a clear fluid; the otolith being in a state of constant vibration. The auditory sac is lined with ciliated epithelial cells. This apparatus acts through the vibrations of sound being transmitted to the organ of hearing. These vibrations are intensified through the movements of the otolith, and are in turn communicated to the auditory nerve in connection

with the sac; the sensation of 'hearing' being thus produced.

48. **HOW THE NERVOUS SYSTEM ACTS.**—The functions of the nervous system, carried on by means of the apparatus just described, consist essentially in the reception by the nerves of sensations derived from the outer world, and in the reaction of these sensations through nerve-action upon the animal. Thus, when touched, the anodon appreciates the sensation through its nerves; the nerves transmit the impulse to the ganglia or nerve-centres, and these centres, reacting upon their appropriate nerves, set in action the muscles which close the shell. Such a series of actions may be termed *reflex;* since the first impression made upon the nerves may be considered as being received by the ganglia, and as being *reflected*, as it were, from these nerve-centres to the muscles or organs concerned in the closure of the shell, or in other acts of the animal's life. Reflex nervous action constitutes the basis of most nervous phenomena, and is exhibited in the higher as well as in lower animals. Every act of the animal's life may thus be presumed to be co-ordinated or regulated by nervous impulses directed after some such fashion as that described. The cephalic ganglia and their nerves supplying the mouth and adjacent parts may further be supposed to regulate chiefly those actions concerned with the appropriation of food, &c. The pedal ganglia supply the muscles of the foot, and the organ of hearing; whilst the branchial ganglia co-ordinate the movements of the viscera, and afford a nervous supply to the mantle and gills. The cephalic ganglia may be regarded as corresponding in function with the brain-mass of higher forms, the pedal nerve-mass as analogous to the system of motor nerve-fibres; and the branchial ganglia, as performing the functions of what is known as the *sympathetic system* of vertebrate animals.

The mussel, as may readily be supposed from its organisation, exhibits few of those phenomena which characterise beings of higher structure and intelligent habits. Thus the opening and closing of the shell present perhaps the most prominent acts of the mussel's life,

and even these acts are not necessarily guided by any very high degree of intelligence or instinct; whilst the absence of extensive powers of locomotion, and the comparatively simple surroundings of the animal's existence, do not render necessary any higher specialisation of its nerve-centres. In animals of higher grade we find certain portions of the nervous system specialised for special duties, and constituting, in the form of eyes, ears, an olfactory or smelling apparatus, &c., what are known as *organs of sense*. Only an organ of hearing, as we have seen, exists in the mussel, which thus possesses a general or diffused sensibility, but hardly exhibits any other nervous structures devoted to the more particular and special appreciation of its surroundings.

49. **REPRODUCTION IN ANODON.**—The *reproductive* system in the anodon consists of an ovary or testis, as the case may be, since these animals, like the anemones, are *diœcious*, and have the sexes situated in different individuals. The distinctive marks between the sexes cannot be perceived externally; and, as in the anemone, the reproductive organs exhibit an essentially similar type of structure in both cases. The *sex-gland*, as the reproductive organ is named, is situated on the foot-mass, and grows very large in the winter and spring, when these animals breed. The reproductive organ exhibits a branched structure, and consists of a gland situated on each side of the middle line of the body, the generative opening being placed—as already remarked in describing the tube-system of the foot—near the outer opening of the organ of Bojanus. The tubular branches of the reproductive gland are lined with epithelial cells, which ultimately develop into eggs or spermatozoöids. The spermatozoöids possess each a minute rod-like body, and a contractile filament or tail. They are discharged into the water along with a quantity of a milky secretion; and those which may be swept into the branchial chamber of female anodons, come in contact with and fertilise the ova therein contained. The eggs are produced sometimes in immense numbers, as many as 3,000,000 ova being produced by a single mussel

in one season. Each egg possesses a layer of albumen, and its vitelline or outer membrane is extended to form a little tubular orifice, the *micropyle*, through which the spermatozoöids enter the egg in fertilisation. The eggs escaping from the ovary into the chambers (fig. 20, *e*, *e*) formed by the union of the gill-layers, are found in great quantities, especially in the cavity of each outer gill, which thus forms a kind of *marsupium* or pouch, in which the eggs undergo development. The yolk-mass of the egg exhibits the process of segmentation, already noticed in the development of hydra; and at an early stage of its progress, the body of the embryo or young animal is seen to be composed of two symmetrical halves, in each of which a distinct set of organs —heart, mouth, stomach, &c.—is developed. These halves in time become fused together, and the two original ventricles of the heart come to unite around the intestine, which thus appears in the adult to pierce the heart, as we have seen. At a certain stage of its development, and whilst within the egg, the embryo may be seen to rotate slowly; the cause of this phenomenon, also observed in the development of other animals, being still obscure.

DEVELOPMENT OF ANODON.—When the embryo of the mussel is hatched, it receives the name of *Glochidium* (fig. 26). It is unlike the parent, and indeed was so named from the fact that when first discovered within the gills of the parent, the embryos were thought to be parasites. A Glochidium-larva, or young anodon, possesses a bivalve shell, the halves of which are of triangular form, and are united at the bases of the triangles. An adductor muscle (fig. 26, B, *a*) is developed for the attachment and closure of the valves, whilst they are kept open, as in the adult, by the action of an external ligament or hinge. The apex of each valve is turned inwards, and is provided with a strong tooth or hook, C, *b*, *b*, which is itself furnished with smaller teeth or spines. These teeth meet when the valves are closed, and in the embryo the shell appears to be frequently opened and shut. The mantle can be already distinguished; and three cells or processes, provided with long hair-like filaments or *cirrhi*, C, *a*,

are developed on the interior of each mantle-lobe. The mouth is of large size, and possesses ciliated edges; and the foot, already formed, but of small size, is developed from the lower surface of the body and behind the mouth. It is provided with a few long threads (A, *a*, and C), which correspond with the *byssus* or 'beard' of the sea-mussels, and by means of which the young anodon may attach itself to fixed objects. The embryos are swept outwards from the

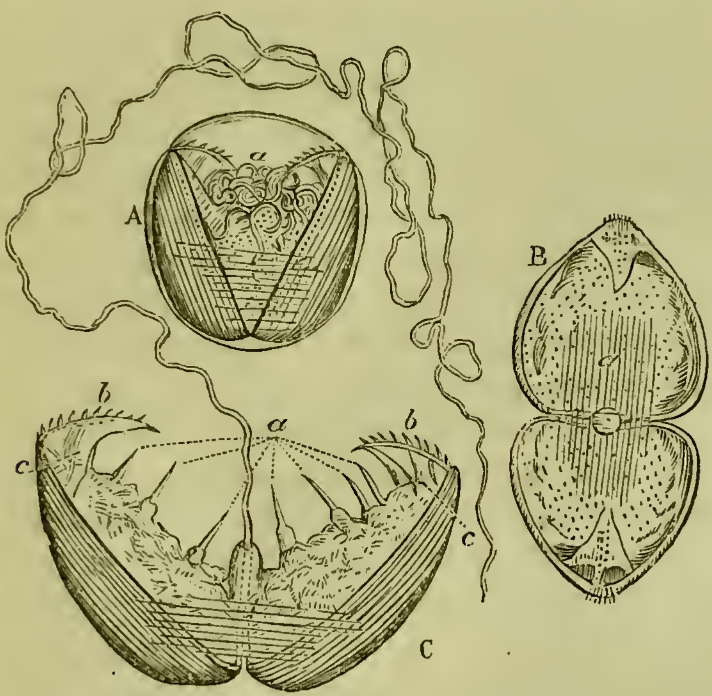

Fig. 26.—Development of Anodon: A, *Glochidium-larva* still within the egg; *a*, byssus; B, shell of glochidium widely opened, shewing adductor muscle, *a*; C, glochidium viewed from the side, shewing hooks of valves, *b*, *b*, muscular folds, *c*, *c*, and the three pairs of filamentous organs, *a*, springing from mantle-lobes along with the extended byssus.

gill-chamber of the parent along with the currents of effete water. They appear to attach themselves to floating objects, and curiously enough are very frequently found attached to the tails of fishes, retaining a firm hold by inserting the points of their shell-valves into the skin of their hosts. In this situation, the already-formed organs grow largely. The gills undergo development; the shell is modified to form the adult structure; the foot becomes larger and loses its byssal filaments; the organ of hearing appears; and with

a few further changes, the glochidium merges into the form of the perfect anodon.

50. **WHY THE MUSSEL IS A HIGHER ANIMAL THAN THE ANEMONE.**—Such being the life-history of the mussel, we may briefly note the more important points which our investigation has exemplified. We firstly observe that the mussel is a higher animal than the anemone from the increased specialisation of its organs and functions. Whilst the anemone had only an imperfect stomach-sac, the digestive system of the mussel is seen to be of a complete kind, inasmuch as, it is *completely shut off from*, and *does not directly communicate with the body-cavity.* We also note that each function in the mussel's body is specialised or split up into various parts, each subserved by a special organ. The function of innervation, for example, which is indistinct in the anemone, is provided for in the mussel by a distinct nervous apparatus; just as the function of nutrition was represented in the latter, not only by a specialised mouth, stomach, intestine, and supplementary glands, but also by a heart and vessels for the circulation of blood, and by gills for the purification of that fluid. In the anemone the functions of circulation and respiration were not specialised or performed by specially developed organs; but were carried on in a diffused manner by the cilia of the endoderm, and by the general inhalation of sea-water into the body-cavity. The further specialisation of certain portions of the nervous system to form organs of sense, is also exemplified by the mussel, which possesses an organ of hearing devoted to the reception and appreciation of sound, but useless for any other purpose.

HOW A KNOWLEDGE OF STRUCTURE FORMS THE BASIS OF CLASSIFICATION.—The manner in which the structure of animals forms a basis for their natural classification may be illustrated by the case before us. Thus the mussel is found to possess a bivalve shell, formed by the pallium or mantle; it wants a distinct head; it has no teeth; and possesses breathing organs in the form of laminar or plate-like gills. Agreeing with the mussel in the possession of these essential characters, a very large number of other

animals may be found. These latter, represented by oysters, cockles, clams, &c., are included with the Anodon in a special *class* of animals named *Lamellibranchiata.* The presence of a shell, the disposition of the nervous system, and a few other characters, constitute points wherein a large number of other animals (such as whelks, cuttle-fishes, pteropods, &c.), belonging to different classes, agree with the Lamellibranchiates. Accordingly, where a large number of animals agree in the fundamental type or plan of structure of their bodies, they are collected together to form a *morphological type* or *sub-kingdom* of animals ; the whelks, cuttle-fishes, lamellibranchiates, and allied animals being thus grouped together to form the sub-kingdom *Mollusca.*

CHAPTER VI.

THE COMMON LOBSTER.

51. The examination of the Lobster or Crayfish introduces us to the study of a great group or sub-kingdom of animals known as the *Annulosa.* This group presents a series of well-defined characters, to be readily discerned in the lobster, and to be duly noted hereafter. Either of the above-named animals will suffice as an example of the Annulose sub-kingdom, but we may select the lobster in preference to the fresh-water crayfish, for the reason that the former is, on the whole, more readily accessible for examination. Both animals, however, very closely resemble one another, although they belong to different *genera* of their class. Thus, scientifically, we name the lobster *Homarus vulgaris;* whilst the crayfish is known as the *Astacus fluviatilis.* The difference in name represents certain stable differences in structure which are perpetuated in the case of each animal, with the result of constituting the lobster a distinct *genus* and *species* from its fresh-water neighbour. The chief points of structural distinction between these animals will be referred to after our examination of the lobster has been completed.

External Features of the Lobster.—The lobster's body may at first sight be seen to be made up of two equal, and, as viewed from the outside, two similar halves. A line drawn along the middle line of the back would divide the animal into two equal halves, each half having appendages similar to those possessed by its neighbour. We thus say that the lobster exhibits *bilateral* or 'two-sided' *symmetry;* a feature also seen in the mussel, but more or less disguised in the latter animal. Externally, like the mussel, the lobster is inclosed in a hard *exoskeleton*, popularly named the 'shell;' although this structure is different in nature from the similarly-named structure in the mussel. The shell of the lobster is formed by the deposition of limy matter in the outer skin or *epidermis* of the animal, and constitutes so general a character of the lobster and its neighbours, that the class to which these animals belong has been named *Crustacea* (Lat. *crusta*, a crust or hard covering). The shell invests the entire body and limbs like a suit of armour, and is found to send certain processes of its substance into the interior of the body for the purpose of supporting the soft parts. The shell, viewed as to its minute structure, is made up of three layers, the outer of which consists of a 'horny, structureless' substance. The middle or areolar layer exhibits spaces or *areolæ;* whilst the third and deeper layer is composed of a substance exhibiting a tubular structure. The shell is beautifully marked with various tints and hues of colour; the red appearance of the cooked lobster being due to a chemical change which takes place in the colouring-matter when the shell is immersed in boiling water.

52. **STRUCTURE OF THE LOBSTER'S BODY.**—The body of the lobster, as indicated by the divisions of the shell, presents for examination two great regions. Of these, the anterior and solidified portion, apparently corresponding to the 'head' (fig. 27, *ca*), ends in front in a pointed spine with toothed edges, named the *rostrum*, *a*; whilst the hinder portion, popularly named the 'tail,' is composed of a series of movable joints. The front part of the body in reality represents the head and thorax or chest

of the animal fused into a single mass, and is hence named the *cephalothorax*, *ca*. Indeed, a cross groove named the *cervical suture* (fig. 27) may be seen on the upper surface of the shelly covering (or *carapace*) of the cephalothorax; this mark corresponding to the union between the segments of the head and those of the chest. The so-called 'tail' of the animal corresponds to the *abdomen*; and like the cephalothorax, it bears on its under surface a number of paired appendages—legs, &c. The body of the lobster appears to consist of twenty joints or *somites*. Fourteen joints are found in the cephalothorax, six being found in the head and eight in the thorax. The abdomen has only six segments, and a small end-piece named the *telson* (fig. 27, *t*), which forms the central portion of the tail-fin, but is not a true somite. It may be noted, however, that some authorities consider the lobster's body to consist of twenty-one segments, regarding the 'telson' as a segment without appendages; and by some zoologists the segments of the cephalothorax are distributed as seven to the head and seven to the thorax or chest. The other characters to be observed in the external inspection of the lobster consist of the opening of the *mouth* and that of the *anus* or vent. The former opens on the under surface of the head, and between certain of the appendages which serve as jaws; whilst the latter opens beneath

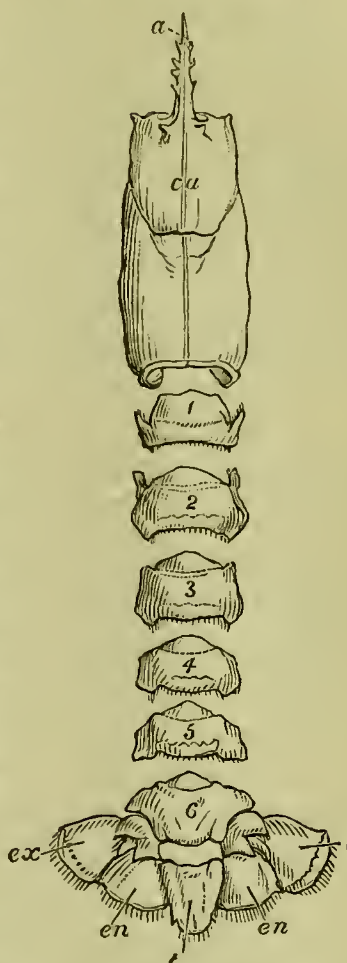

Fig. 27.—Morphology of Lobster; parts of the exoskeleton or shell separated from each other, and viewed from above: *a*, 'beak' or 'rostrum;' *ca*, carapace covering the cephalothorax; 1 to 6, the six segments of the abdomen; *ex*, *ex*, exopodites, which, together with the similarly broadened endopodites, *en*, *en*, of the 6th segment, and the 'telson,' *t*, form the tail-fin.

the telson, at the opposite extremity of the body to the mouth.

The lobster is well known to exhibit considerable activity; walking about by means of its numerous legs, and swimming backwards by means of the quick contractions of the broad fin formed by the last joint of the tail and its appendages. The animal acquires a knowledge of its surroundings through its organs of sense, consisting of stalked eyes, organs of hearing, and feelers exercising the sense of touch; and we thus note that the lobster may be accounted an animal of more active habits, and, if the comparison be admissible, of altogether higher organisation than the mussel.

53. **The Plan on which the Lobster's Body is constructed—Homology.**—The lobster's body, when more minutely examined, is found to present a remarkable similarity in the type or plan upon which its segments are constructed. We thus become aware of a certain broad likeness between the joints of the body which underlies all the modifications of form and function which the segments present. And to the likeness which may be supposed to exist between parts which are fundamentally the same, the term *Homology* is applied. This principle of tracing such likenesses between the parts of animals and plants is of great service to the biologist, and an excellent example of its application is therefore afforded by the examination of the animal before us. The segments of the abdomen are found to present the simplest condition of parts. Selecting, say the third joint of this region, we find that it includes a *body-piece* and *appendages*. The body is composed of an arched upper portion, the *tergum* (fig. 28, A, *t*), and of a flattened lower part, the *sternum*, *s*. The point of union on each side between the sternum and tergum is extended downwards to form a side-plate, named the *pleuron*, *pl*. The appendages are attached to the sternum, and consist of a pair of organs named *swimmerets* or *abdominal feet*. Each swimmeret is made up of a joint (*protopodite* or *basipodite*, *pt*), serving as its base, and attaching it to the sternum, and of two other flattened pieces, an outer and an inner, attached to the protopodite,

and respectively named the *exopodite*, *ex*, and *endopodite*, *en*. The tergum presents a smooth surface in front for articulation with the preceding segment, and the hinder part of the tergum in turn overlaps the succeeding joint. The pleuron of each side also possesses a smooth surface on its front half, which is covered by the pleuron of the joint before.

Bearing in mind these elements and their arrangement, as exhibited in the third joint of the abdomen, we find essentially the same type of structure to be presented by the fourth and fifth joints. The sixth segment (fig. 27, 6), however, appears at first to be differently constructed from its neighbours, but on a closer examination we see that it

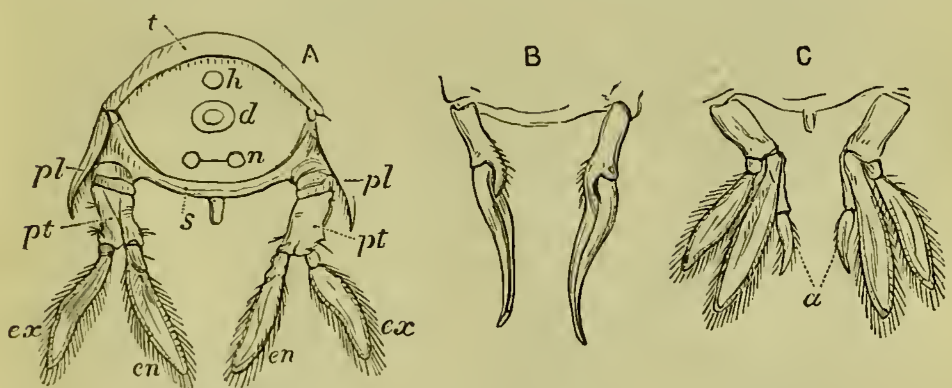

Fig. 28.—Morphology of Lobster: A, third abdominal segment viewed from behind; *ex*, *ex*, exopodites; *en*, *en*, endopodites; *pl*, *pl*, pleura; *pt*, protopodites; *s*, sternum; *t*, tergum; *h*, situation of heart, *d*, of digestive system, and *n*, of nervous system, represented diagrammatically. B, the horny appendages of the first abdominal segment of the male. C, appendages of the second abdominal segment, shewing the little processes, *a*, borne on the endopodite.

only differs from them, firstly, in having its protopodite, exopodite, *ex*, and endopodite, *en*, greatly expanded, and fringed with *setæ* or soft bristles; secondly, in having the exopodites, *ex*, *ex*, divided crosswise by a joint; and thirdly, by having the flat telson or tail-piece, *t*, attached to it as a central appendage. The expanded appendages of the sixth joint of the tail and the telson together make up the tail-fin of the lobster. The telson by some naturalists is regarded, as already remarked, as a seventh segment without appendages, but this view is probably incorrect; the telson being an *azygos*, or odd appendage unattached to any joint, and consisting essentially of an extension of the upper wall of the

sixth joint. The second segment of the abdomen presents little variation from the typical or third joint, save that its endopodite possesses a little inner process (fig. 28, C, *a*); and the first segment is similar to the others, except for the modification of its swimmerets or appendages. The latter in the male lobster consist of two grooved or spoon-like processes (fig. 28, B) of horny nature, and in the female of two flexible and undivided appendages. In so far, therefore, as the joints of the abdomen are concerned, there can be no difficulty in referring them to one evident type or plan of structure.

54. **THE CEPHALOTHORAX.**—The *cephalothorax* (fig. 27, *ca*), composed of united head and chest segments, at first sight appears to be constructed on a type quite different from that of the abdominal joints. By inspecting the lower surface of the cephalothorax, however, we are able to detect small and narrow sterna lying between the eight joints and their legs and other appendages which belong to the thorax; and we may gain a still clearer idea of the typically distinct nature of the segments of this region, by tracing the appendages which belong to them. Thus the last joint of the thorax, or that lying in front of the first abdominal segment, possesses, as its appendages, a pair of walking-limbs (fig. 29, 13). Each of these limbs in the young state consisted of a protopodite, exopodite, and endopodite, like the abdominal appendages; but as development proceeded, the exopodite disappeared, leaving the protopodite, *p*, and endopodite, *en*, in the form of a limb. The joints of which the walking-legs are composed are named—beginning with the basal joint, or that corresponding to the protopodite—coxopodite, basipodite, ischopodite, meropodite, carpopodite, propodite, and dactylopodite, making a total of seven joints in all. The next segment of the chest, proceeding forwards, bears a pair of appendages, similarly converted into limbs; but an additional process, not developed in the segments of the abdomen, is also found in this second thoracic segment. This new process is named the *epipodite*. It is seen also in the third pair of legs (fig. 29, 12, *ep*), and should, perhaps, be accounted a typical appendage of the lobster's body. It

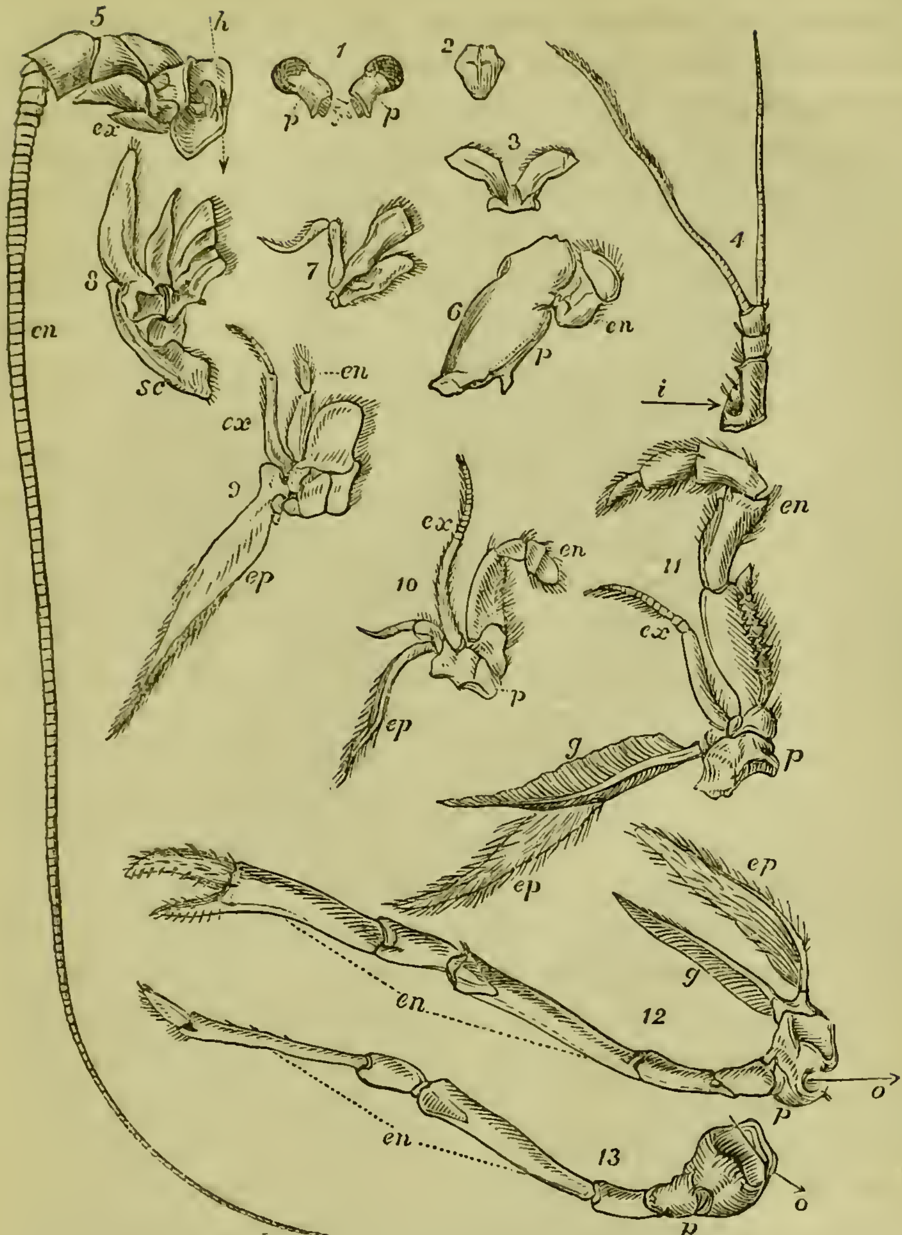

Fig. 29.—Morphology of Lobster, shewing appendages of one side of cephalothorax from before backwards: 1, eyes borne on stalks; 2, labrum; 3, metastoma; 4, one of the antennules; 5, one of the antennæ; 6, a mandible; 7, one of the first pair of maxillæ; 8, one of the second pair of maxillæ; 9, one of the first pair of maxillipedes or foot-jaws; 10, one of the second, and 11, one of the third pair of foot-jaws; 12, one of the third pair of walking-legs of the female; 13, one of the hindmost (fifth) pair of walking-limbs of the male. The reference letters refer to the same parts in all the figures: *ex*, exopodite; *en*, endopodite; *ep*, epipodite; *p*, protopodite; *sc*, scaphognathite; *g*, gill; *h*, opening of *green gland*; *i*, opening of auditory sac; *o*, *o*, generative openings.

extends from the base of the legs upwards into the gill-cavity of the animal, and separates the branchiæ or gills. The pair of walking-limbs (fig. 29, 12) borne on the next thoracic segment in advance, like the remaining two pairs, is also provided with epipodites, *ep*, and with nipping-claws or *chelæ*, which become, as every one knows, of very large size in the most anterior or fifth pair of walking-limbs. The 'nippers' are formed by a development from the last joint but one (propodite) of the limb; the last joint or dactylopodite budding out therefrom, and in time coming to oppose the preceding joint as the movable nipping-claw. The fourth and fifth pairs of walking-legs—still counting from behind forwards—bear epipodites like the other two pairs, and also consist of a basipodite and greatly developed endopodite. These five pairs of walking-limbs, representing the appendages of the five hinder segments of the thorax, are succeeded by three pairs of appendages named *maxillipedes* or 'foot-jaws;' the latter belonging to the three front segments of this region. These foot-jaws (fig. 29, 9, 10, 11) each consist of a protopodite, *p*, exopodite, *ex*, endopodite, *en*, and epipodite, *ep*. The transition from jaws to limbs is well seen in the hindmost or third pair of the maxillipedes, 11; the endopodites, *en*, of which are like their limb-like representatives of the walking-legs; whilst their protopodites, *p*, are sharp and jaw-like. The exopodites, *ex*, of all the foot-jaws are of small size; and the front pair of maxillipedes, 9, is soft, their appendages, *ex*, *en*, being foliaceous or leaf-like.

The Head.—The segments in front of that bearing the first pair of foot-jaws belong to the head. The hindmost segment of the head bears a pair of appendages, 8, known as the second pair of *maxillæ*, or lesser jaws; whilst the preceding segment bears similar organs—the first pair of maxillæ, 7. Each maxilla consists of a protopodite, small endopodite, exopodite, and epipodite. The epipodites and exopodites of the second pair of maxillæ are greatly enlarged, and constitute what are known as *scaphognathites*, *sc*, or spoon-shaped structures used for baling water out of the gill-chamber. The scaphognathite of each side is

contained within a groove (*cervical groove*), which marks the division between the head and thorax on the side of the cephalothorax, at the front margin of the gill-chamber. The epipodites and exopodites of the first pair of maxillæ are rudimentary, the bulk of these appendages being constituted by the endopodites. The segment in front of that bearing the first pair of maxillæ is the fourth segment of the head, counting from before backwards ; and this fourth segment bears a pair of stout jaws or mandibles, 6, as its appendages. The mouth opens between the *mandibles*, which consist each of a largely developed and toothed protopodite, *p*, forming the bulk of the jaw, and of a small endopodite, *en*, forming a little 'feeler' or *palp;* the exopodite and epipodite being undeveloped. In front, the mouth-opening is bounded by a little shelly piece, existing in the middle line of the body, and known as the *labrum* or upper lip, 2. Behind the mouth, a forked plate named the *metastoma*, 3, labium, or lower lip, also exists. Neither of these pieces, however, can be properly regarded as being true appendages of the segments on which they are borne. They may perhaps be ranked along with the *telson* (fig. 27, *t*) and *rostrum*, *a*, or front spine of the shell, as median developments of their respective regions. The palpi of the mandibles are useful in directing food-particles towards the mouth.

The remaining three segments of the head, it must be noted, bend sharply upwards, forming the *cephalic* or *head-flexure*. The sterna, or lower pieces of these segments, consequently come to lie in a plane almost at right angles to that of the sterna of the hinder segments of the cephalothorax. This disposition of parts doubtless exists in connection with the modification of these anterior segments to form the true 'head' of the animal. Their appendages are modified to serve as organs of sense, and are directed forwards rather than downwards, as is the case with those of all the other joints of the body. The third segment of the head possesses appendages in the form of the greater pair of *antennæ* or feelers, 5 ; each of which organs consists of a basal joint, or protopodite, a very long jointed endo-

podite, *en*, and a very small and scale-like exopodite, *ex*, lying at the base of the endopodite. The second head-segment carries the lesser pair of feelers, or *antennules*, 4, as its appendages; the latter organs consisting of protopodite, exopodite, and endopodite. The first segment of head and body alike, bears the eyes, 1, which are compound organs, and are borne on short movable stalks or *peduncles*. Each eye-stalk represents a protopodite, *p*, without any other pieces developed in connection therewith.

The only remaining feature worthy of special notice in the morphology of the shell, consists in the great development of the sides of the carapace covering the thorax. The shell in this region is expanded at the sides or pleura (par. 53) to form coverings which inclose and protect the gills (fig. 30, *t*), and which are accordingly named *branchiostegites*. The *gill* or *branchial chamber* thus formed, opens both below and behind on each side by the narrow space existing between the bases of the walking-limbs and the branchiostegites; whilst in front, the chamber may be found to open into a space existing at the *cervical groove* already mentioned, and in which the 'scaphognathite' (*sc*, fig. 29, 8) of the second pair of maxillæ is contained.

55. **What Homology implies.**—A review of our examination of the shell and of its segments and appendages, clearly shews us that the shell is built up of segments constructed on a type most clearly seen in the joints of the abdomen (fig. 28, A). The segments of the lobster's body, as indicated by the exoskeleton, are therefore seen to be *homologous*—that is, they exhibit a similarity in fundamental structure. As the segments are placed one after the other in a series, the arrangement also exemplifies what is known as *serial homology*. Thus it matters not, as far as their homological correspondence is concerned, that the form or functions of the segments and their appendages are widely different. The eye-stalk, feeler, jaw, limb, and swimmeret are essentially similar in nature, however modified in outward appearance or use. And that this assertion is not merely hypothetical, may be proved in two ways. It may firstly be shewn, through *development*, that the segments

and their appendages, however different in the adult, are similar in the young animal. Or secondly, by an examination of other and adult crustaceans, parts which are greatly modified in the lobster can be shewn to exhibit very close resemblances to the type of the swimmerets, and also to undergo other and greater modifications—thus proving the adaptation of one type to an almost infinite variety of purposes.

Moulting of the Shell.—As is well known, the lobsters, crabs, and their neighbours periodically 'moult' or cast the outer shelly layer of their body; this process being scientifically known under the name of *ecdysis*. The skin remains soft for a time, until the blood-vessels bring new calcareous or limy matter, which becomes deposited in the soft skin, and forms the new shell. The process of moulting the shell is of so complete a nature, that the coverings of the limbs, eyes, and all other shelly parts are thrown off, and in due time renewed.

56. **DIGESTIVE SYSTEM OF LOBSTER.**—The study of the

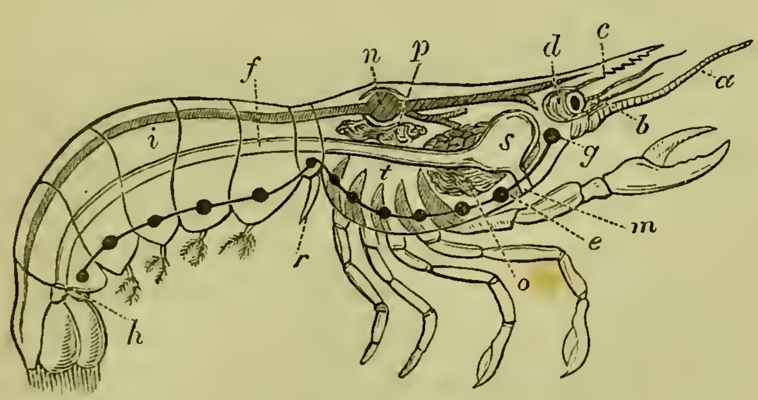

Fig. 30.—Diagrammatic (Longitudinal) Section of Lobster: *a*, one of the greater antennæ; *b*, one of the antennules; *c*, rostrum of shell; *d*, eye; *e*, infra-œsophageal ganglion; *f*, intestine; *g*, supra-œsophageal ganglion; *h*, anus; *i*, superior abdominal artery; *m*, mouth; *n*, heart; *o*, liver; *p*, generative organs; *r*, one of the appendages of first abdominal segment, horny in the male; *s*, stomach; *t*, placed above the gills represented as attached to the bases of the legs. The nervous ganglia are depicted as situated in the ventral or lower surface of the body.

lobster's internal structure and physiology may appropriately be introduced by the examination of the general

arrangement of its organs. Thus, as indicated in a transverse section of the body (fig. 28, A), the heart, *h*, is seen to exist dorsally or in the back region. The digestive system, *d*, occupies the middle aspect or axis of the body; whilst the nervous system, *n*, exists as a chain of nerve cords and ganglia on the ventral aspect or floor of the body. We further find that the gullet is encircled by a collar of nervous matter (fig. 30), and that one of the chief nerve-masses (fig. 30, *g*) of the body lies above the œsophagus or gullet, and is connected by the nerve-collar with the masses below the gullet. The mouth (fig. 30, *m*) exists at the anterior extremity of the body, and opens, as we have seen, between the mandibles (fig. 29, 6); whilst the anus or vent (fig. 30, *h*) is placed at the opposite extremity, and opens beneath the telson.

Stomach and Liver.—The mouth leads into a short, wide gullet which expands into a large stomach (fig. 30, *s*). Both the gullet and stomach are lined by a horny layer, derived from the shelly outer layer of the body; and when the process of ecdysis takes place, the hard structures of the gullet and stomach are cast off and secreted anew, along with the outer shell. The stomach of the lobster is divided into two parts, a large anterior or *cardiac* portion, and a smaller hinder part, the *pyloric* extremity. The intestine, *f*, is given off from the latter part of the stomach, and runs backwards in a straight course to the anus. It gives off a little pouch-like sac, and also exhibits an increase of its dimensions near the vent. Internally, the surface of the intestine is smooth. The stomach itself contains certain limy pieces, developed in the walls of its cardiac portion, and known collectively as the *gastric skeleton*. These pieces serve as teeth, and triturate or grind down the food admitted to the stomach. The chief element in the gastric skeleton is shaped like the letter T; the limb of the letter extending backwards, and its cross-piece lying transversely in the stomach. The three extremities of the T-shaped structure are connected each with a strong tooth of brownish colour. By means of appropriate muscles, this apparatus

is set in action, and divides the food passing between the teeth. The pyloric part of the stomach has thick walls, the sides of which are furnished with hairs adapted for straining off the coarser particles of the food, and thus preventing such particles from entering the intestine. The lobster, like the mussel, has therefore a digestive tube com-

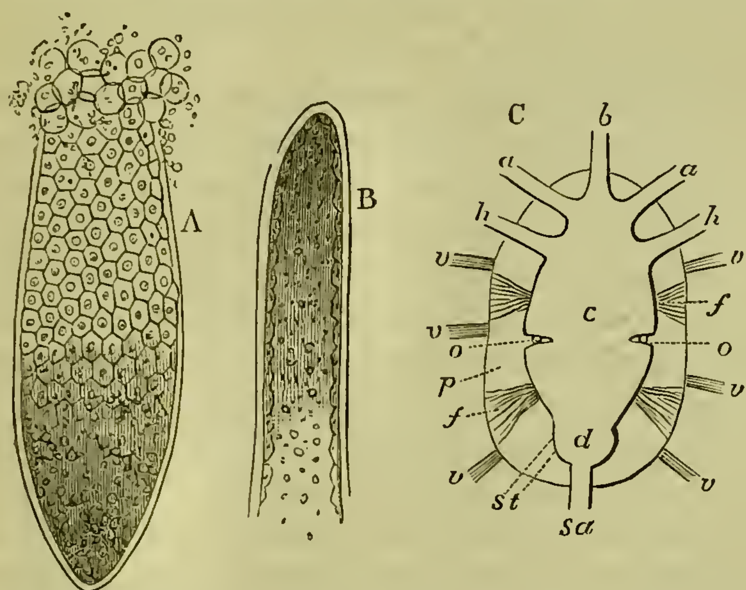

Fig. 31.—Viscera of Lobster : A, one of the tubules of the liver of the Cray-fish (largely magnified), shewing the development of its bile-secreting cells. The cells of the lower portion of the tubule are less highly developed than those at its superior or open extremity. B, a single tubule of the lobster's liver magnified, shewing the lining of epithelial cells which secrete the bile. The interior of the tube is occupied by bile and granular matter. C, diagram of the heart and pericardium of lobster viewed from above. The pericardium, *p*, incloses the heart, which gives off anteriorly an *ophthalmic* artery, *b*, and *antennary*, *a*, and *visceral*, *h*, vessels also. The fibrous bands attaching the heart to the pericardium are represented at *f*, *f*; and two of the openings of the pericardium into the heart-cavity, *c*, are represented at *o*, *o*. The superior abdominal artery given off from the posterior dilated extremity of the heart, *d*, is represented at *sa*, and the course of the sternal artery at *st*. The vessels returning pure blood to the pericardium from the gills are marked *v*, *v*.

pletely shut off from the body-cavity, and, like the latter, possesses supplementary glands. A gland exists in the mouth, which is supposed to furnish the *saliva* or mouth-fluid. The liver (fig. 30, *o*) is very large, and exists as a long mass of yellow colour situated on each side of the cephalothorax. The microscopic structure of the liver (fig.

31, A, B) shews it to be composed of branching cæcal or pocket-like tubes lined by epithelial cells. It thus closely resembles the liver of the mussel in minute structure. The bile secreted in the tubules of the liver is brought in contact with the food by two *hepatic ducts* or tubes, one of which opens on each side of the pyloric portion of the stomach, at the point where the intestine is given off from the latter structure.

57. **HEART AND BLOOD-VESSELS OF THE LOBSTER.**—As in the mussel, a heart and blood-vessels are provided for the distribution of the blood or nutritive fluid. The blood of the lobster is almost colourless, and when microscopically examined, is seen to contain colourless nucleated corpuscles, which, like those of the mussel, send out long pseudopodial processes, causing each corpuscle to appear like an amœba. The heart lies within a *pericardium* or *pericardial sinus* (figs. 30 and 31, C, *p*), and is situated beneath the carapace, and just behind the cervical suture on the upper surface of that structure. It consists of a sac of roughly hexagonal shape, and is attached to the interior of the pericardium by fibres. If the hinder part of the carapace be removed from a lobster during life, and after the sensibility of the animal has been destroyed by immersing it for a few moments in boiling water, the heart may be seen pulsating within the pericardium. The heart is composed of muscular fibres which form the thick walls of the organ. Six apertures are to be perceived in the front portion of the heart. These openings, two of which are represented at *o*, *o* (fig. 31, C), lead from the pericardium, and are protected on the inner surface of the heart by valves, preventing the escape of blood which has flowed into the heart by these apertures. Three *arteries* or blood-vessels, distributing pure blood throughout the body, originate in part from the upper and front portion of the heart; these vessels supplying the eyes, antennæ, and other parts of the head; whilst at the lower portion of the front of the heart two (*hepatic*) vessels (fig. 31, C, *h*, *h*) pass to the liver. Behind, the heart gives off firstly the large *sternal artery* (figs. 31, C, and 32, *st*), which descends to the floor of the

body between the last two nervous ganglia of the cephalothorax, and divides into branches supplying the lower aspect of the body with blood. The second great vessel given off from the posterior extremity of the heart is the *superior abdominal artery* (figs. 30, *i*; 31, C; and 32, *sa*), which runs along the upper surface of the intestine, and supplies the abdominal segments. The arteries divide amongst the tissues into minute or *capillary vessels*, as described in the mussel; and finally enlarge to form *veins*, which in the lobster are represented by *sinuses* or ill-defined spaces existing between the muscles and organs of the body. These sinuses collect the venous or impure blood, and finally empty their contents into a large vein, the *median ventral sinus* (fig. 32, *c*, *c*), lying along the floor of the body in the middle line. From this latter sinus, the venous blood passes to the *branchiæ* or *gills* (figs. 30, *t*, and 32, *g*, *g*), to be purified by receiving oxygen from the water admitted to the breathing organs.

58. **THE GILLS OR BREATHING ORGANS OF THE LOBSTER.** —The gills are contained in the sides of the cephalothorax (fig. 30), and are protected, as already described, by the branchiostegites of that region. They number twenty on each side, and are attached to the bases of the legs and to the sides of the body. Thus the epipodites of the second and third pair of foot-jaws, and those of the first three pairs of walking-legs, each bear a gill; whilst the remaining fourteen gills of each side are attached to the sides of the body contained within the cephalothorax. Each gill consists of a main or central stem, which, when cut across, shews the presence of two great blood-vessels, running one up the outer, and the other along the inner aspect of the gill. The former vessel is a continuation of the great ventral sinus or vein, and is therefore that by which the venous blood is returned to the gill to be purified. The inner vessel of each gill, on the other hand, conveys the purified blood away from the gill, and is continued into certain vessels named *branchio-cardiac canals* (figs. 31, C, and 32, *v*, *v*), which open into the pericardium. Each gill further consists of a large number of fine filaments borne on the central stem of vessels;

and the entire structure has not inaptly been compared to a bottle-brush ; each filament of the brush representing a network of minute blood-vessels, in which the venous blood is exposed to the action of the oxygen. The water containing the latter gas is admitted to the breathing-chamber by the lower and hinder edges of the branchiostegites—that is, through the narrow cleft left between the base of the walking-legs and the lower edge of the gill-chamber. Thus admitted to the gill-chamber, the water flows over the gills, and gives up its oxygen for the purification of the blood. Becoming thus useless and effete by the absorption of carbonic acid from the blood, the water is got rid of by the incessant movements of the spoon-like epipodites or 'scaphognathites' (fig. 29, 8, *sc*) of the second pair of maxillæ, which bale out the water in front, and thus cause a fresh inflow from behind. The movements of the legs and their epipodites, to which the gills are attached, also aid in the free circulation and renewal of the water in the gill-chamber. It may be noted that cilia are completely absent from the gills of the lobster, and, indeed, from the tissues generally ; the function of these filaments in maintaining currents of

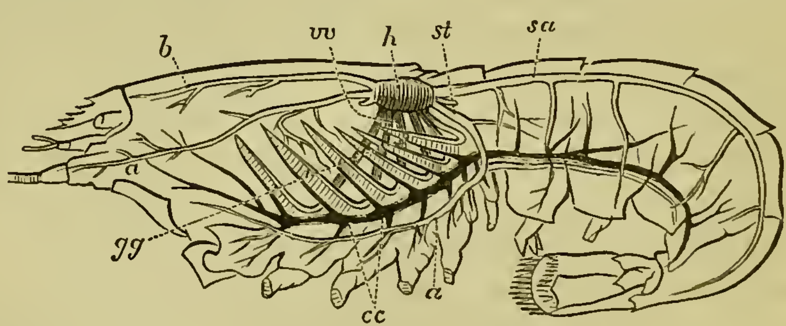

Fig. 32.—Circulation in the Lobster. The heart, *h*, is represented as giving off the antennary and hepatic arteries, *a*, and the ophthalmic vessels, *b*. Behind, the superior abdominal artery, *sa*, and the sternal artery, *st*, originate. The great ventral sinus or vein is represented at *c*, *c*, and by this channel the blood is conveyed to the gills, *g*, *g*. Thence it is returned to the pericardium and heart by the branchio-cardiac canals, *v*, *v*.

water through the gill-chamber, devolving chiefly upon the scaphognathite, as we have seen.

CIRCULATION IN THE LOBSTER.—The heart of the lobster,

like that of the mussel, may be termed *arterial* or *systemic*, in that it serves merely to circulate pure blood throughout the body (fig. 32), and does not assist in driving the venous blood to the breathing-organs. The blood becoming venous, is returned, as we have seen, to the gills for purification; and thence flows into the pericardium and heart, to be circulated anew through the system.

59. **Green Glands of Lobster.**—In the mussel an excreting or depurating structure, the 'organ of Bojanus,' was observed to aid the gills in their work of getting rid of the waste matters of the body. In the lobster it is highly probable that two curious *green glands*—so named from their colour —which are contained in the head, one at the base of each antenna, represent the functions of kidneys, in that they excrete waste matters of nitrogenous kind. The green glands are closely related to two large, thin-walled sacs, and each sac opens outwardly by a little pore readily seen on the under surface of the basal joint of the antenna (fig. 29, 5, *h*).

60. **MUSCLES OF LOBSTER.**—The various movements of the lobster are performed, like those of the anodon, by means of specially-developed organs known as *muscles*. Each muscle, when stimulated, as in nature, through the nervous system, possesses the power of contracting or shortening itself, and thus serves to approximate its points of attachment. Unlike those of vertebrated animals, however, the muscles of the lobster are contained *within* the hard parts or exoskeleton to which they are attached; whilst the joints of the lobster's body are also constructed on a different plan from those of higher forms. All the muscles of the lobster are of the *striped* or *striated* kind (fig. 19); each muscular fibre being invested in a sheath or *sarcolemma* of connective tissue. The fibrils of the muscle, unlike those of anodon, exhibit the alternating arrangement of darker and lighter transverse markings, mentioned when considering the muscular structure of the mollusc. And it is curious to note, that even the muscles of the intestine in the lobster are composed of striped fibres; the muscular layers of the alimentary canal in higher animals being composed of unstriped tissue.

61. **NERVOUS SYSTEM OF LOBSTER.**—The *nervous system* of the lobster (figs. 30 and 33) consists of a series of thirteen *ganglia* or nerve-knots, lying along the floor of the body in the middle line, and united by commissures or connecting-nerves. From this chief nervous axis, nerves are supplied to the other parts of the body. The study of the early life-history of the lobster would seem to indicate that each segment of the body originally possesses a pair of ganglia. As development proceeds, however, the originally separate ganglia unite more or less completely; the three front pairs of ganglia becoming fused together to form the large *cephalic* or *cerebral* ganglion (fig. 33, *c*). This ganglion, also named the 'brain' or *supra-œsophageal* ganglion, from its supposed analogy to the brain of higher animals and its position respectively, is situated in the head-region, near the base of the antennæ, and in front of the mouth. Nerves, *o*, *o*, are supplied to the eyes and antennæ, and to the viscera from the cephalic ganglion. This ganglion is connected by two cords, co^1, co^1, encircling the gullet, *g*, with a still larger ganglion, named the *post-oral*, or *infra-œsophageal* ganglion, *i*, and which probably represents in itself five (or six) united pairs of ganglia. From the post-oral ganglion, the maxillæ, foot-jaws, and the neighbouring regions of the head and chest, receive their nervous supply. The remaining five pairs of ganglia, *th*, corresponding to the remaining five segments of the thorax, and connected by

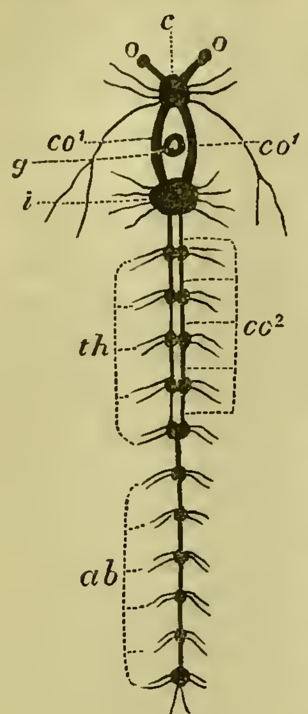

Fig. 33.—Nervous system of Lobster: *c*, cephalic or supra-œsophageal ganglion; co^1, co^1, commissures or nerve-cords connecting the cephalic with the infra-œsophageal ganglion, *i*, and surrounding the gullet, *g*; *th*, five thoracic ganglia, shewing their double nature and the double commissures, co^2, which connect them; *ab*, six abdominal ganglia connected by single commissural cords; *o*, *o*, optic nerves.

double commissural nerve-cords, co^2, lie in the floor of the cephalothorax; and six ganglia, *ab*, exist in the abdomen, this arrangement giving one nerve-mass to each segment of the latter region. The ganglion of the sixth segment is larger than its neighbours; and the nerve-cord connecting the abdominal ganglia is single in its nature.

Organs of Sense, and Structure of Nerves.—The organs of sense of the lobster consist of the feelers, of large compound eyes, and of auditory organs; the eyes being supported, as already noted, on movable stalks. The surface of each eye is divided into a large number of quadrangular 'facets' or small spaces, as may be seen by inspecting the organs. These facets are the outer surfaces of conical structures, which appear to be separated from one another by pigment or colouring matter, and to be connected below with the special or *optic* nerve exercising the sense of sight. The manner in which the functions of this eye are performed, has not been accurately determined. And a knowledge of the structure and relations of the parts forming the eye of higher animals, is necessary for the due understanding of the morphology of the analogous organ in the lobster. The sense of *touch* is subserved by the antennæ and antennules; the intimate structure of these bodies shewing a plentiful distribution of nerve-filaments within their substance. No olfactory organ, exercising the sense of smell, is known to be represented in the lobster; but an organ of hearing or *auditory sac* is developed as in the mussel. This latter organ is contained within the basal joint of each antennule, and opens thereupon by a minute aperture surrounded by fine hairs. The sac is formed by an involution of the shelly layer of the body, and contains a ridge, fringed with delicate hairs. At the bases of these hairs, the terminal filaments of the auditory nerve, or nerve of hearing, are found. The sac itself is filled with water, and also contains small grains of sand, named *otoconia* or *otoliths*, which have gained admittance from the exterior. The delicate hairs, along with the particles of sand, have the function of intensifying the vibrations of sound, which, as in the mussel,

are transmitted to the auditory nerve, and give rise to the sensation of hearing. The nerves of the lobster, when examined microscopically, are seen to be composed of delicate fibres; each fibre (fig. 34, *a*) consisting of an outer structureless membrane containing *nuclei*. Within this outer membrane, the internal part of the nerve-fibre may be seen to consist of a clear fluid matter, or of a granular substance; whilst occasionally the central part of the fibre may itself exhibit an appearance of being divided into finer fibres, such an appearance being named *fibrillation*. The nerve-ganglia are composed of large *ganglionic corpuscles* (fig. 34, *b*), which are nucleated, and give off fibres or prolongations of their substance. A delicate investing sheath may be found to invest the nerve-cords. This sheath is named the *neurilemma*, and is analogous to the *sarcolemma* of muscle (par. 60).

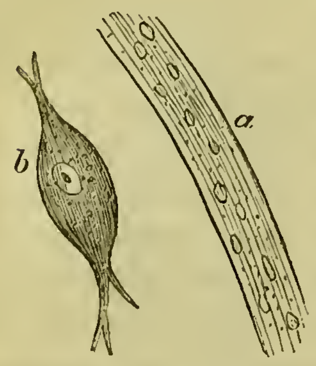

Fig. 34.—Structure of the Nerves of Lobster: *a*, nerve-fibre, shewing nuclei imbedded in its outer membrane; *b*, oval nerve-cell from ganglion, shewing contained nucleus and nucleolus, and processes.

62. **REPRODUCTIVE ORGANS OF LOBSTER.**—The sexes in the lobster are contained in separate individuals as in the mussel; and the male animals may be distinguished from the females by their having shorter pleura, and by the horny nature of the first pair of abdominal feet or swimmerets. The testes or male organs exist in the form of two tubular structures, which lie beneath the heart, partly in the thorax, and partly in the abdomen. Behind, the tubes unite, but they are completely separated at their front portions, save for a connecting branch which exists near the anterior extremity. The duct by means of which the male fluid is conveyed from each testis is named the *vas deferens*. It originates near the middle of the testis, and passes as a simple tube to open at the base of the last walking or thoracic leg of its own side. The ovaries or female organs consist of two long sacs or tubes of blackish hue, occupying much the same position as the reproductive

organs in the male. The surface of the ovary usually exhibits a roughened appearance, produced by the eggs contained within it. The ovaries are fused together towards their front extremity; and the *oviduct* of each, by which the eggs are conveyed from the ovary to the exterior, opens at the base or first joint of the third walking or thoracic limb. The spermatozoöids of the lobster are not actively moving filaments, but consist of inert cells of elongated shape (fig. 35), bearing three pointed filaments at one extremity. The spermatozoöids are glued together by a viscid secretion into bundles named *spermatophores.* At the breeding season, the eggs pass from the ovary through the oviduct, and become attached by means of a glutinous secretion to the swimmerets of the mother; hundreds of eggs thus becoming attached to the abdominal appendages, by the animal bending the tail under the body so as to receive the eggs as they escape from the genital openings.

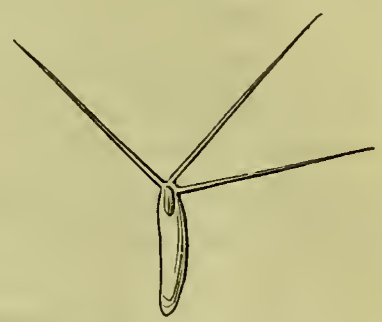

Fig. 35.—Spermatozoöid of Lobster, shewing three elongated processes (highly magnified).

63. **DEVELOPMENT OF LOBSTER.**—The eggs, duly impregnated by contact with the spermatozoöids, undergo the earlier stages of their development while thus attached to the parent body, and are also subjected to the favouring influence of freshly aerated water when retained in this situation. The result of the primary stages of development is the production of the blastoderm or germinal membrane from which the embryo is gradually fashioned. Only a part of the yolk of the lobster's egg undergoes segmentation, and produces the blastoderm. The young embryo or *Zoea*-larva is unlike the perfect lobster. As it is developed, and whilst still within the egg (fig. 36, *a*), the ventral or lower side of the body, or that on which the nervous system is placed, is seen to lie nearest the surface of the ovum; and when it leaves the egg (fig. 36, *b*), it is seen to possess five pairs of thoracic legs, resembling those of the

adult. These legs, however, are provided with exopodites, which disappear when the adult stage is attained, leaving the endopodite of itself, as we have seen, to represent the limb. The two hinder pairs of foot-jaws present much the same conformation as the walking-legs of the young form; the maxillipedes, however, retaining their exopodites throughout life. The tail at this stage is already jointed, but is destitute of its appendages or swimmerets; and small gills are developed on the limbs behind the foot-jaws. All

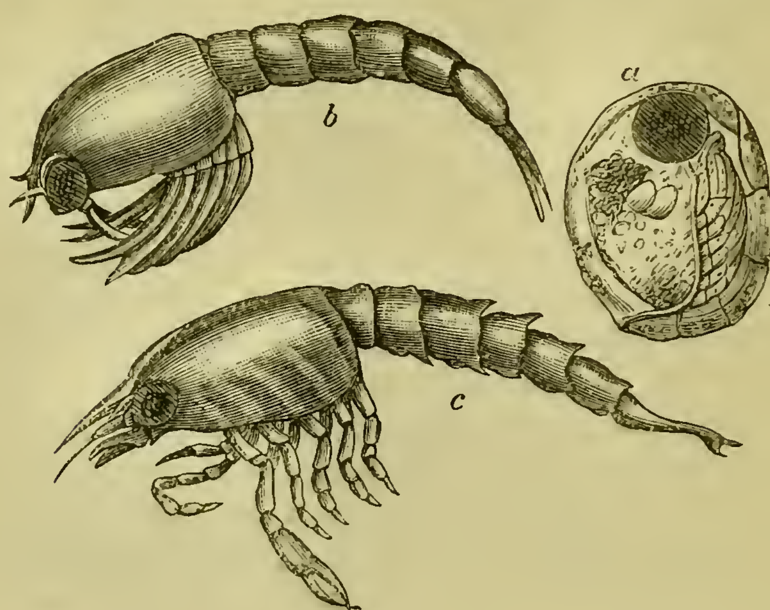

Fig. 36.—Development of Lobster: *a*, embryo within the egg; *b*, embryo or *Zoea* just hatched; *c*, embryo after first moult.

the appendages of the body appear at first as little buds, which, like the thoracic limbs, exhibit, in their earlier stages, a striking similarity of form. The young larva (fig. 36, *c*) appears to moult its 'shell' or outer skin frequently during the course of its development. This process of 'ecdysis,' or moulting, provides for the due increase of the young animal; and with the development of the abdominal feet, and through the continuous growth of the tissues and organs generally, the adult stage is soon attained, and the process of development duly completed.

64. **Differences between the Lobster and Crayfish.**—The differences between the fresh-water crayfish (*Astacus fluvia-*

tilis) and the lobster, besides those derived from the habitat of the animals, consist in the smaller number of gills possessed by the crayfish, whilst the latter has longer hepatic cæca or liver-tubules than the lobster. The reproductive organs of the two animals also exhibit certain structural differences; and whilst the intestine in the crayfish wants the little cæcal or pouch-like sac placed close to its termination in the lobster, it possesses a like sac near the stomach, this latter appendage being small in the lobster. Externally, the two animals differ, in that whilst the 'telson' is jointed in the crayfish, it is undivided (fig. 27, *t*) in the lobster. The rostrum or beak of the carapace is also larger in the crayfish than in its marine neighbour.

65. **How the Lobster illustrates the Characters of its Sub-Kingdom.**—The lobster may be selected as a highly typical representative of the sub-kingdom of animals known as the *Annulosa*. The characters of this group may be well studied in the lobster. Thus, firstly, the segmented or jointed nature of the body is clearly seen, this character giving origin to the name 'Annulosa,' derived from the Latin *annulus*, a ring or segment; and to the synonymous term *Articulata* (Lat. *articulus*, a joint). The general disposition of the organs of the body presents us with a second character of importance in the recognition of annulose animals. Thus in these forms, as we have observed in the lobster (fig. 28, A), the heart, *h*, lies dorsally, and the nervous system, *n*, ventrally, or on the floor of the body; whilst the digestive system, *d*, occupies a median position. Then we note that, as in Annulosa generally, each segment of the body possesses appendages of some kind; that these appendages exist *in pairs;* and that, as regards their relations to the body, they are turned towards the ventral or nervous aspect of the animal. The *jaws* are seen to consist simply of limbs or of ordinary appendages specially modified for the work of mastication. The mouth and anterior part of the alimentary system turns towards the nervous or neural aspect of the body, and is surrounded, as we have seen, by the nervous centres; whilst, finally, in the course of development, the ventral or

nervous aspect of the body is that which appears on the surface of the egg during development.

66. **The Nearest Allies of the Lobster.**—In that the lobster possesses jointed legs, truly articulated or jointed to the body, it agrees with a large number of other Annulose animals, such as centipedes (*Myriapoda*); insects (*Insecta*); and spiders, scorpions, and mites (*Arachnida*). These three classes, along with the lobster and its neighbours, are accordingly known as *Arthropoda*, or Annulose animals possessing jointed limbs. The lobster and all its allies (barnacles, water-fleas, king-crabs, shrimps, crabs, &c.), forming of themselves the class *Crustacea*, are distinguished in their turn from the insects, centipedes, spiders, &c., by the possession of more than four pairs of walking-legs; by the appendages of the body being borne by both thorax and abdomen; by the presence of two pairs of antennæ; and by respiration being performed by means of gills or branchiæ.

How the Relationship of Animals is to be Studied.—We thus note that the Crustacea constitute a large class or group of Annulose animals, the bodies of which are constructed on one fundamental type. When we meet with variations of form or structure, often of considerable extent, in this and in other groups of animals, it may lastly be noted, that such variations are produced not by the development of new types of form, but merely through modifications of the original and single plan of the class. The tracing of the *development* and *homologies* of widely different members of a class will assuredly shew their near relationship; just, indeed, as we have traced the likeness and connection between the swimmerets and the other appendages of the lobster—a likeness not discernible in the fully-grown animal, but clearly to be seen in the development of the young organism.

CHAPTER VII.

THE STRUCTURE, PHYSIOLOGY, AND DEVELOPMENT OF THE COMMON FROG.

67. **THE FROG A VERTEBRATE ANIMAL.**—The animals which have formed the subjects of the preceding lessons might be grouped together under the one collective name of *Invertebrata;* since in none of them have we found any traces of that important structure, so familiar to us as occurring in higher animals, and which we term the *spine*, *vertebral* column, or *backbone*. The presence of this latter structure, or of its representative, is thus the distinguishing mark, so to speak, of the highest sub-kingdom of animals. This division we name *Vertebrata*, and included within its limits are five well-defined groups of animals. These latter are represented by the fishes (*Pisces*); frogs, newts, &c. (*Amphibia*); reptiles, such as lizards, snakes, tortoises, and crocodiles (*Reptilia*); birds (*Aves*); and mammals (*Mammalia*), including man himself. As an illustration of the general characters, structure, and physiology of a vertebrate animal, we may select the common frog (*Rana temporaria*), belonging to the class *Amphibia*. The examination of such a familiar animal will serve not only to impress the principal points in vertebrate structure on the mind, but will also aid us in comprehending the essential differences between the highest animals and those representatives of lower groups which we have already examined.

68. **THE EXTERNAL CHARACTERS OF THE FROG.**—With the outward appearance of the frog everybody is familiar. But there are a few points valuable as zoological characters which may be derived from an external inspection of the animal. Thus we note a similar disposition of its outward surface and appendages to that we observed in the lobster. We find that the body of the frog may be divided into two equal halves by a line drawn through the middle

of the body from before backwards, and either on the back or lower surface. The animal, in other words, is *bilaterally symmetrical.* This symmetry, as in the lobster, extends to the appendages of the body, since we find that each half of the body so divided possesses two appendages, the *limbs;* those of one side being the exact counterparts of their opposite neighbours. We do not find this outward symmetry to be thoroughly preserved in the internal parts of the body; but the external configuration of the body thus indicated, is common to all vertebrate animals.

The head and body are readily noted, but no distinct *neck* or line of separation between the two regions can be distinguished, externally at least. No tail is present in the full-grown animal. The body is covered by a smooth skin of yellowish colour, diversified with darker markings. The skin is destitute of scales or other hard coverings, and thus presents no traces of an exoskeleton, such as we found to be developed in the lobster or mussel. A very slight examination of the frog's body, however, reveals the fact that it possesses a series of hard parts or bones *within* its body, and that consequently an *endoskeleton* is thus present. Behind the head the fore-limbs are developed on the sides of the body; whilst the hind-limbs, which are much longer than their anterior neighbours, are borne at the posterior extremity of the body. The front-limbs possess four toes or fingers forming the 'hand;' the hind-legs terminating in five toes composing the foot. The fingers are free from each other, but the five toes are webbed. The third finger is the largest of the hand, and the fourth the largest toe of the foot. No distinct 'nails' are developed on either fingers or toes in the frog, but a little horny growth, named the *tarsal tubercle*, exists at the base or root of the great toe; this latter being the innermost toe of the foot.

In its natural position, and when resting, the hinder part of the back is seen to exhibit a sharp prominence caused by the union of the haunch-bones with the spine. The prominent eyes furnished with eyelids for their protection constitute noticeable features in the external appearance of the frog. And although no outer ears are to be dis-

cerned, the *tympanic membrane*, or that covering the 'drum of the ear,' may be seen existing as a prominent surface of tightly-stretched black skin on each side of the head, just behind the eye. The only apertures to be discovered on the external surface of the frog's body are the anterior nostrils and mouth, and the posterior opening of the body. This latter aperture is the external opening of the *cloaca*, or common cavity, into which not only indigestible and effete matters from the digestive system, but also the secretion of the kidneys and the generative products, are expelled.

69. **Movements of the Frog.**—The movements of the frog on land are performed by aid of its limbs, after the well-known fashion, the animal taking leaps of considerable extent; whilst in water the webbed hind-feet form effective swimming organs. The frog possesses considerable sensibility to outward circumstances and things. It thus leaps away from an observer when touched; it captures its prey, consisting of insects, with much dexterity by a peculiar arrangement of the tongue, to be hereafter noted; and it is capable of emitting a sound—the well-known 'croak' of these animals. When at rest, it sits in a semi-erect posture, and exhibits movements of the nostrils and body connected with breathing, and of the eyelids, especially when the eye itself is irritated in any way.

GENERAL PLAN OF THE FROG'S STRUCTURE.—An idea of the general disposition and arrangement of the parts of the frog's body may be readily gained by even a cursory examination of its internal structure. Thus the interior of the body consists apparently of one great cavity (fig. 37) corresponding to both chest and abdomen of higher animals. Within this cavity are contained the various organs by means of which the ordinary processes of life in the frog are carried on; these organs being represented by the digestive apparatus, by the heart, lungs, kidneys, reproductive organs, &c., and also by a series of nerve-ganglia, collectively named the *sympathetic system* of nerves. No separation between chest and abdomen, such as is seen in any quadruped or mammal, is thus developed

in the frog; and the single body-cavity of the animal, from its correspondence with the two cavities of higher forms, is named the *pleuro-peritoneal cavity* (fig. 37, *e*, *e*). The pleura is the membrane which lines the chest, and the peritoneum that which lines the abdomen of mammalia; and hence the single membrane lining the body-cavity of the frog, and investing the viscera or organs, is named the *pleuro-peritoneal membrane*, *b*, *b*. A little closer investigation of the frog's body, however, shews us that in the roof or dorsal part of the body-cavity, corresponding to the animal's back, the spine or backbone, *v*, is situated. And we further note that the *skull* or skeleton of the head may be regarded, for the present at least, as the front termination of the spine. The spine and skull in fact, form a continuous tube or casing, within which the chief nervous centres of the frog—consisting of the *brain* and *spinal cord*—are protected and inclosed. Hence we might diagrammatise the general arrangement or plan of the frog's body by a simple figure such as that represented at A, fig. 38. The body of the frog, and that of every other Vertebrate animal, consists, when seen in transverse or cross section, of two parallel tubes—one, the upper or *neural* tube, p^1, containing the chief centres of the nervous system, n^2; the other tube being the *visceral* or ventral tube, p^2. The latter lies below the neural tube, and contains the sympathetic nerves, n^1, and the general viscera, *a*, *h*, of the body. A cross-section of the frog's body at about its middle, shews that the upper tube of the diagram corresponds to the tube formed by the spine (fig. 37, *v*) which incloses the spinal cord. The lower or visceral tube of the diagram is seen to

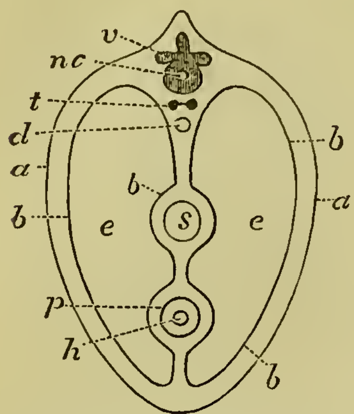

Fig. 37.—Diagrammatic Transverse Section of Frog's Body: *a*, *a*, walls of body; *b*, *b*, folds of pleuro-peritoneal membrane; *d*, dorsal artery; *e*, *e*, pleuro-peritoneal cavity; *h*, heart; *nc*, neural canal of spine; *p*, pericardium; *s*, digestive system; *t*, sympathetic nervous system; *v*, vertebra.

be represented in nature by the walls of the body (fig. 37, *a*, *a*), inclosing the body or pleuro-peritoneal cavity, *e*, *e*, with its contained organs. If we imagine the head of the frog to be cut crosswise, the same disposition of parts will be seen. The upper or neural tube will correspond to the skull and its cavity containing the brain, whilst the lower or ventral tube finds its representative in the mouth-cavity.

70. **COMPARISON OF A VERTEBRATE AND AN INVERTEBRATE ANIMAL.**—It is highly instructive to compare the section of the Vertebrate animal, represented by the case of the frog, with that of some Invertebrate form. Thus we may represent the body of an invertebrate animal in transverse section by the diagram at B, fig. 38. This diagram, for example, will

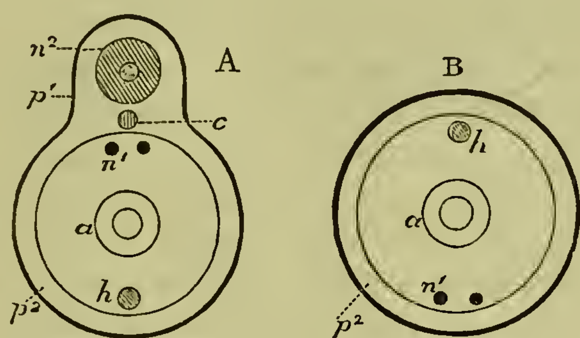

Fig. 38.—Comparative Morphology of Vertebrate and Invertebrate: A, transverse (diagrammatic) section of Vertebrate; *a*, digestive, and *h*, blood systems; *c*, notochord; n^1, sympathetic nervous system; n^2, cerebro-spinal nervous system; p^1, walls of neural tube; p^2, body-walls or visceral tube. B, similar section of Invertebrate; p^2, body-walls; n^1, nervous system. (Other references as in A.)

represent the cross-section of such a form as the lobster; and as we have already seen, that animal exhibits no traces of any structure corresponding with the spine of the frog, nor indeed does the body of any other invertebrate. Therefore we represent the body of the lobster and that of all other invertebrata as consisting of a single tube, p^2, only. A comparison of the invertebrate diagram with that of the vertebrate will shew us that the lower tube of the latter represents the entire body of the former; and that the upper or neural tube of the vertebrate is entirely unrepresented in invertebrate animals.

The disposition of parts thus revealed, forms a marked characteristic of vertebrata. Shortly summed up, the characters thus found to be peculiar to vertebrata may be stated as consisting, firstly, in the fact of their nervous centres, n^2, being separated and partitioned off from the other parts of the body, through their inclosure in the protecting case formed by the skull and backbone, p^1, or by the representatives of these structures. In the invertebrate, on the contrary (fig. 38, B), the nervous centres, n^1, are not separated from the other organs, but are contained with the latter in the single tube which represents the entire body. And secondly, whilst the nerve-centres of the vertebrate are situated dorsally, those of the invertebrate are placed on the ventral or lower aspect of the body; the digestive system, *a*, in both cases occupying a median position.

71. **HOW THE CHARACTERS OF VERTEBRATE ANIMALS ARE TO BE TRACED IN THEIR DEVELOPMENT.**—A third point distinctive of vertebrate animals may be found in the presence of the skull and spine, or their equivalents. A brief sketch of the early stages of the development of the egg of the frog will shew that the spine is as peculiar to vertebrata as are the characters already mentioned. Thus, after the mulberry stage of yolk-segmentation of the egg (fig. 7), the blastoderm or germinal membrane, with its outer layer or *epiblast*, its middle layer or *mesoblast*, and its inner layer or *hypoblast*, is formed. On the surface of the blastoderm a little furrow named the *primitive groove* next appears. The edges of this groove grow upwards in the form of two folds, named the *laminæ dorsales*, and finally unite in the middle line, thus converting the groove into a tube; whilst other parts of the blastoderm, the *laminæ ventrales*, grow downwards, and also unite to form a lower tube. These two tubes eventually become the upper or neural tube (fig. 38, A, p^1), and the lower or visceral tube, p^2, of the adult animal. Meanwhile, in the floor of the primitive groove or dorsal tube of the embryo, a soft rod-like body has become developed, and comes ultimately to lie in the partition which separates the dorsal from the ventral tube. This body is the *notochord* (fig.

38, A, *c*), or *chorda dorsalis;* and as development proceeds, it is replaced in the vast majority of vertebrates by the spine or backbone. The nervous system is formed in the young animal from the epiblast or outer layer of the blastoderm which lines the primitive groove; the outer skin or *epidermis* being, curiously enough, also formed from the epiblast. The hypoblast gives origin to the *epithelium* or lining membrane of the digestive system; and the middle layer or mesoblast produces the remaining structures of the body. The history of the vertebrate's development, therefore, shews us, that the presence of a primitive groove in the developing egg; the formation of an upper and lower tube; the development therein of the nervous system and other organs respectively; and finally, the presence of the rod-like notochord, which is destined to be replaced by the spine, constitute so many points in the early life of the vertebrate, which foreshadow and ultimately become stable characters of the adult. These characters, thus outlined, as it were, from the first, in the special development of all vertebrata, have no representatives in the embryonic history of any invertebrate animal.

72. **The Limbs of Vertebrata.**—The limbs of vertebrate animals never exceed in number those of the frog. They always exist in pairs; are supported by extensions of the endoskeleton, and are turned away from the *neural* aspect of the body, or that on which the nervous system is situated. As seen in the lobster and in many other Invertebrata, the limbs may greatly exceed the number of vertebrate appendages. In Invertebrata, the limbs are further turned towards the neural aspect of the body, and are encased in the exoskeleton; but have no internal axis such as is found in vertebrate limbs (fig. 40). Certain other characters of vertebrata, illustrated by the study of the frog, will be duly noted as our examination proceeds.

73. **The Skin of the Frog, and its Structure.**—Commencing the history of the frog with the examination of the *skin* or investing membrane of its body, we find that this membrane represents the exoskeleton of lower forms; since in many vertebrate animals it may develop hard structures, such

as scales or bony plates, which serve to protect their possessors. In the frog, as we have already noted, no such appendages—save the teeth, as will be presently noted—are developed. The skin consists of an upper layer, the *epidermis* or 'scarf-skin' (fig. 39, *b*), and of a lower layer,

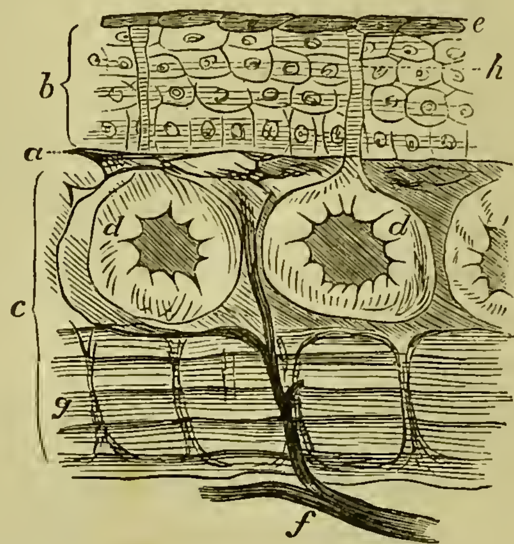

Fig. 39.—Vertical Section of Frog's Skin (magnified): *a*, pigment cells; *b*, epidermis; *c*, dermis; *d*, *d*, skin-glands; *e*, outer layer of epidermis; *f*, nerve-filament; *g*, deep layer of dermis; *h*, duct of skin-gland.

the *dermis*, or true skin, *c*. The names *ecteron* and *enderon* are sometimes used as synonymous with epidermis and dermis respectively. We have seen that the epidermis is formed from the epiblast or outer layer of the blastoderm, along with the nervous system; the dermis being developed from the mesoblast. At the apertures of the body, the skin becomes continuous with the epithelial lining of the digestive system. In the frog the skin is notable as containing a large number of simple pouch-like glands, *d*, *d*, opening on its surface; these glands having to do with the excretory function of this membrane. Microscopically examined, the skin is seen to contain numerous black pigment or colour cells, *a*, of irregular outline, which are most numerous in the dermis, and which, under stimulation, exhibit remarkable changes in shape. The epidermis is thinner than the deeper layer, and is composed of layers

of cells, *b*; those nearest the upper surface, *e*, being flattened and non-nucleated; whilst the deeper epidermal cells are of oval shape, contain nuclei, granules, and sometimes pigment spots, and are placed vertically in the skin surface. The dermis is made up of tissues named by physiologists elastic and white fibrous tissues. Its upper layer, *a*, contains many pigment cells; whilst beneath this layer the skin-glands, *d*, *d*, already mentioned, are seen. These latter are little sacs lined by large nucleated cells. Each sac opens on the epidermal surface by means of a little tube or duct, *h*. The deepest layer of the dermis, *g*, is composed of connective tissue; the fibres of the tissue lying parallel with the surface of the skin. The skin grows by the development of new cells from below, which gradually take the place of the older cells, as the latter are worn away and shed from the body-surface.

Functions of the Skin in the Frog.—The skin of the frog becomes intimately related in its functions to the process of respiration or breathing in these animals, through its serving to excrete a large quantity of the carbonic acid and watery vapour representing part of the body-waste. This act is performed by the skin or cutaneous glands just noted; and the importance of the skin in the vital processes of the frog has been experimentally proved by these animals continuing to live for long periods under water, and also when deprived of their lungs; the essential part of the lung-functions in such circumstances being carried on by the skin. A much larger supply of blood is sent to the skin (fig. 45, *mv*) in the frog and its kind, than is usually seen in other groups of vertebrata; and from the blood thus sent to the skin, certain waste matters are excreted.

74. **THE FROG'S SKELETON, AND ITS MODE OF FORMATION.**—The consideration of the *endoskeleton* of the frog may naturally follow upon that of the exoskeleton. The teeth of all vertebrates, it may be noted, are structures which belong not to the endoskeleton but to the dermis, since they are formed by the latter layer. The teeth might therefore have more properly been included in the list of exoskeletal ele-

ments, but their description may more appropriately, perhaps, be delayed until the digestive system is examined.

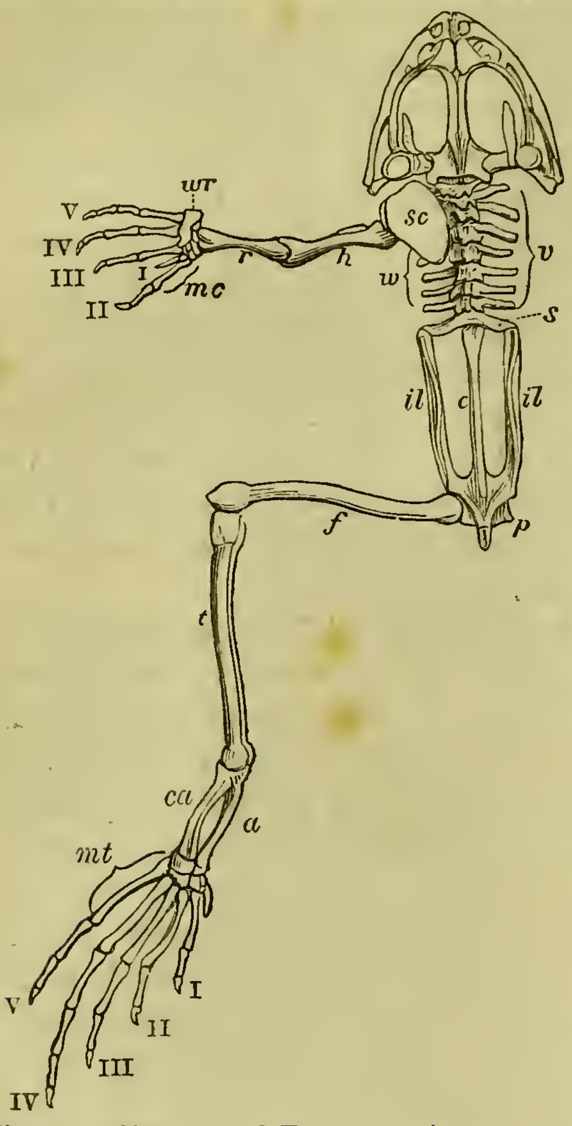

Fig. 40.—Skeleton of Frog: *v*, spine; *s*, sacrum; *il*, *il*, ilia; *c*, coccyx or urostyle; *p*, pubis; *w*, transverse processes of vertebræ; *sc*, scapula; *h*, humerus; *r*, forearm bones; *wr*, wrist; *mc*, metacarpus; I, II, III, IV, V, fingers; *f*, femur; *t*, leg; *a*, astragalus; *ca*, os calcis; *mt*, metatarsus; I, II, III, IV, V, toes.

The endoskeleton of the frog, like that of all vertebrates, in respect of its truly *internal* nature, constitutes a highly characteristic feature of its organisation. The entire skeleton may be divided into two portions — an *axial* part (fig. 40), represented by the skull and spine; and an *appendicular* portion, represented by the limbs, and their attachments to the axis. The skull and spine form the foundation or main axis of the body, just indeed as the notochord, of which they are the representatives, constitutes of itself the first indications of the endoskeleton which appear in the developing embryo. The skeleton of the adult frog has in fact passed through successive stages of development in the process of its conversion into bone. The notochord, at first of gelatinous nature, became cellular. Then the tissues known as *connective tissue* and *cartilage* or 'gristle' were developed; and from each of these latter structures *bone*

was ultimately produced. Connective tissue, which thus shares in the formation of the skeleton, also forms an important part of the body-structures, supporting and binding together the various membranes. This tissue is well seen, for example, in the tendons or sinews which attach muscles to bones. It consists, in tendons, of parallel bundles of fibres, composed of that variety of connective tissue specially known as *white fibrous tissue.* Cartilage is a more familiar constituent of the bodies of vertebrate animals; and exhibits large cells, imbedded in a granular or non-granular base or *matrix.* The skeleton of the young frog or tadpole consists almost wholly of cartilage at one period of its development; and in the skeleton of the fully-grown animal, cartilaginous elements may be seen entering into the formation of many portions, such as the sternum or breast-bone, the skull, the ends of the bones and transverse processes of the vertebræ, and the hinder extremity of the spine. Similarly, in the young frog, the limbs and their supporting arches are composed of cartilage, around and within which, bony matter is gradually deposited. Thus bone is developed both from connective tissue and from cartilage; these tissues forming in either case a *matrix* in which salts of lime (chiefly consisting of phosphate and carbonate of lime), brought by the blood-vessels of either primary tissue, are gradually deposited. The cranial or skull-bones exemplify *membrane-bones*, or those which have been formed by limy matter being deposited in connective tissue; whilst the limb bones, as already remarked, illustrate *cartilage-bones*, or those produced from a cartilaginous matrix. The further explanation of the structure and manner of formation of connective tissue, cartilage, and bone, belongs to physiology and histology proper; whilst the disposition of the purely cartilaginous elements in the frog's skull is of too complicated a nature for description in the present instance.

75. **The Frog's Vertebral Column or Spine.**—The spine or backbone of the frog presents for examination a front portion, composed of nine distinct pieces (fig. 40, *v*), each named a *vertebra*, and of a hinder portion not separ-

able into distinct elements, and named the *urostyle* or *coccyx*, *c*. The latter structure probably represents more than two united vertebræ. Each vertebra consists of a body-piece or *centrum*, having its front surface, or that next the skull, concave, and its hinder surface convex. Such a vertebra is named *procœlous;* the concave anterior surface of each, fitting the convex hinder surface of the vertebra before. From the dorsal or upper aspect of the centrum or body—as exemplified by the third vertebra of the frog's spine—two processes originate, and unite in the middle line to form a ring or arch—the *neural canal*—which projects upwards in a bony spine, the *neural or spinous process*. The neural canals of the various vertebræ, when united, form the dorsal or neural tube of the body (pars. 69, 70), continuous with the cavity of the skull, and in which the spinal cord is lodged. From each side of the body of the vertebra a long *transverse* process, *w*, arises. And two pairs of *zygapophyses* or *articular* processes, serving to attach the vertebra to its neighbours, are also developed.

All the vertebræ of the frog, except the first and two last, conform to this type; although, indeed, the entire nine are as clearly homologous with one another, as are the segments of the lobster's body. The first vertebra is named the *atlas*. Its body projects forwards, between the two hinder processes or condyles of the skull; its spinous process is rudimentary, and it has no transverse processes. This atlas vertebra articulates with and supports the skull. The eighth vertebra closely resembles the third and its neighbours, save that at each extremity of its body it has a hollow facet or articular process. The ninth vertebra forms the *sacrum*, *s;* a bone which in man is wedged in between the haunches or hip-bones. The sacrum in the frog is convex in front, and has two short convex processes behind, by means of which it is united to the corresponding concavities on the urostyle or coccyx. The transverse processes of the sacrum are large, and articulate with the *ilia* or haunch-bones, *il*, *il*. The *urostyle* or *coccyx* (fig. 40, *c*), forming the last segment of the spine, bears a dorsal ridge, and appears to consist of the ossified or bony sheath of the hinder part of

the notochord. The chief (*sciatic*) nerve of the leg passes from the spinal cord to its limb on each side of the coccyx through a special aperture existing at the anterior part of the latter structure. The spine of the frog thus forms a continuous bony axis, containing and protecting the spinal cord, one of the great nerve-centres of the animal, and affording a solid foundation or point of attachment for the other parts of the skeleton.

As every one knows, the slender bony pieces found in most vertebrate animals and named *ribs*, spring from the spine, and are attached to the sternum or breast-bone in front. The frog has no ribs, and the absence of these structures is clearly a gain to the animal in respect of its peculiar leaping movements. The breathing of the frog is also carried on in a somewhat peculiar fashion in consequence of the absence of the ribs, which in higher animals form the walls of the thorax or chest, and are intimately concerned in the movements of respiration.

76. **THE SKULL OF THE FROG.**—The morphology of the frog's skull can only be briefly glanced at in the present instance, inasmuch as an acquaintance with general as well as human anatomy is necessary for the full and complete understanding of its structure. A reference to the accompanying illustration will serve to render the description of the skull intelligible to junior students. The skull consists of the *cranium proper*, forming the bony case inclosing the brain, and of the *face*, composed of facial bones. The cranium of the frog, as already remarked, consists of a cartilaginous portion, and of bony elements also. The description of the latter can alone be satisfactorily attempted here, and should be practically illustrated, along with the description of the other parts of the skeleton, by the inspection of a prepared skeleton of the animal.

Looking at the general morphology of the skull, we observe posteriorly the *foramen magnum* (fig. 41, *FM*), a large aperture, through which the brain, contained within the cranial cavity, becomes continuous with the spinal cord. This aperture bears on each side a little convex process, the *occipital condyle*, *CO*, which fits into a corresponding

concavity on the atlas vertebra. The bones on which the condyles are situated are named the *exoccipital bones*, *EO*; these bones having the foramen magnum, *FM*, between them. Two bones named *pro-otic*, *PrO*, lie on the outer sides of the exoccipital bones, and contain the anterior parts of the organs of hearing; whilst in front of the exoccipital bones,

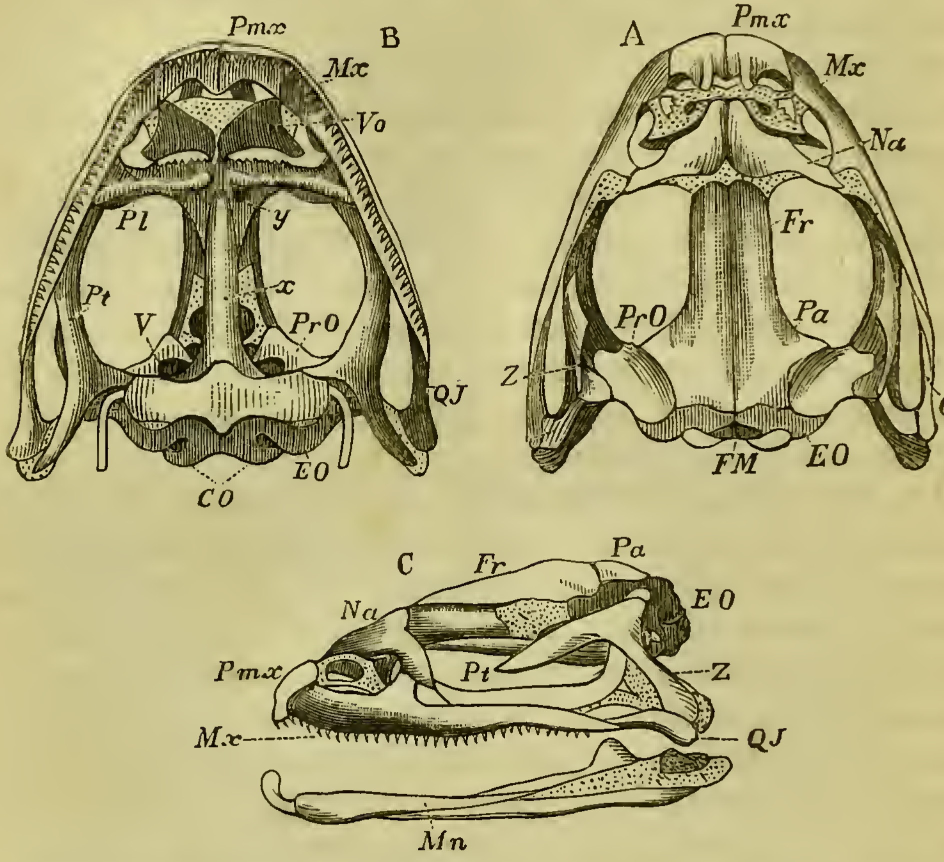

Fig. 41.—Skull of Frog: A, viewed from above; B, from below; and C, from the side; *CO*, occipital condyles; *PaFr*, parieto-frontal bones; *PrO*, pro-otic bones; *Na*, nasal; *Mx*, maxillary; *Pmx*, premaxillary; *EO*, exoccipital; *QJ*, quadrato-jugal bones; *FM*, foramen magnum; *x*, parasphenoid bones; *y*, girdle-bone; *Vo*, vomers; *Z*, squamosal; *Mn*, mandible.

two long bones named *parieto-frontal bones*, *PaFr*, extend forwards, and form part of the roof of the skull. The *nasal* or nose bones, *Na*, lie before the parieto-frontals; and the extreme front of the skull is formed by the two *premaxillary bones*, *Pmx*, which correspond with the front portions of the upper jaw in higher animals.

The floor or base of the skull is formed in part by a

dagger-shaped bone, seen in many fishes, and named the *parasphenoid*, *x*. Perhaps one of the most characteristic features of the frog's skull consists in the presence of the *os ceinture* or *girdle-bone*, *y*, a cartilage bone of compound nature, which assists in the formation of the cranial cavity, and also forms the nostrils in front. The *palatine* bones are two rod-like bones, *Pl*, extending outwards from the parasphenoid bone; and the *vomers*, *Vo*, lie in front of each palatine bone. The upper jaw is formed by the *maxilla*, *Mx*, and its front part or premaxilla, *Pmx*, already named; whilst at the hinder part of each maxilla a small bone, *QJ* (the *quadrato-jugal*), is situated. This latter in turn unites with the free extremity of another bone, the *squamosal*, *Z*, which lies between the pro-otic bone of each side and the articulation or junction of the lower jaw with the skull. The *lower jaw* or *mandible*, *Mn*, appears to be composed of two halves or *rami*, united by bony union at the *symphysis* or 'chin.' Each half or ramus consists of three distinct elements; and the lower jaw itself articulates with the skull by means of two bodies known as the *suspensorial cartilages*. The upper extremity of each of these cartilages is developed as a separate bone, which in birds and reptiles articulates the lower jaw to the skull under the name of the *quadrate bone*. In the frog, however, this structure unites with another element to form the quadrato-jugal bone, *QJ*, already mentioned. In mammalia, the lower jaw articulates directly and of itself with the squamosal part of the skull; the quadrate bone of lower forms being pushed upwards in the development of mammalia into the skull, and forming one of the small bones (*malleus*) of the internal ear.

The Hyoid Bone.—The *hyoid bone* of the frog, or that supporting the tongue, forms part of the skull, and consists of a broad *body*, from which are given off a pair of long and slender anterior processes or *cornua*, two shorter *posterior cornua*, and two pairs of smaller processes. The hyoid bone undergoes a series of developmental changes of exceeding interest in connection with the growth and metamorphosis of the frog and its breathing organs.

77. **Skeleton of the Limbs.**—The skeleton of the fore-limbs (fig. 40) presents for consideration a breast-bone, shoulder-girdle, and the limb proper. The breast-bone or *sternum* (fig. 42) of the frog, is placed in the middle

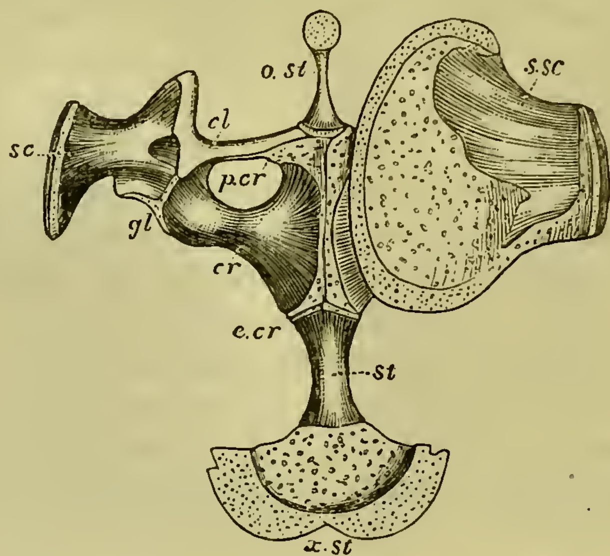

Fig. 42.—Shoulder-girdle of Frog: *st,* sternum; *xst,* xiphisternum; *ssc,* suprascapula; *sc,* scapula; *cl,* clavicle; *ost,* omosternum; *gl,* glenoid cavity; *cr,* coracoid bone; *pcr,* precoracoid; *ecr,* epicoracoid.

line of the lower aspect of the body. It is composed chiefly of cartilage, and consists of an anterior or front portion, bony in its nature, and named the *omosternum, ost;* of a middle cartilage, with a bony covering, representing and named accordingly the true *sternum, st;* and of a hinder part, the *xiphisternum, xst.* The omosternum is separated from the sternum by the intervening coracoid bones, *cr.* The shoulder-girdle, supporting each fore-limb, consists of the semi-cartilaginous *suprascapula, ssc;* of the bony *scapula* or 'shoulder-blade' proper, *sc,* which exhibits below a concavity, *gl* (the *glenoid fossa*), for the articulation of the humerus or upper arm-bone; of a *coracoid bone, cr,* represented in most mammals by a mere process of the shoulder-blade; and of a *clavicle* or 'collar-bone,' *cl,* lying between the coracoid and scapula and the breastbone. Cartilaginous pieces named the *precoracoid, pcr,* and *epicoracoid, ecr,*

are also developed in connection with the coracoid bone. The bones of each arm or fore-limb (fig. 40) consist firstly of an upper arm-bone or *humerus*, *h*. The apparently single bone of the forearm articulating above with the lower end of the humerus and below with the wrist, is composed of two united bones, respectively known as the *radius* and *ulna*, *r*; the former lying to the thumb side of the limb. The carpus or wrist, *wr*, is composed in the frog of six bones, and the palm consists of five *metacarpal bones*, *mc*. The *digits* or fingers number four; the fifth, the *pollex* or *thumb*, being rudimentary, and being represented by a small metacarpal bone only. The second finger, or that next the rudimentary thumb, and the third digit, are composed each of two separate pieces or *phalanges*. The fourth and fifth fingers each consist of three phalanges. It is curious to note that, at the breeding-season, a little process is developed in male frogs near the thumb.

Pronation and Supination.—The fore-limb of the frog, in consequence of the united condition of the bones of its forearm, cannot perform those movements so well seen in man, and which are named *pronation* and *supination*. These movements—illustrated, as regards pronation, when the palm of the hand is directed downwards, the radius crossing the ulna; and as regards supination, when the palm is turned upwards, the two bones lying side by side—are performed by the radius revolving round the ulna as round a pivot. It is evident that such an action cannot take place in the frog, the natural position of the frog's arm being that of pronation.

78. **THE PELVIS AND HINDER-LIMBS.**—The hinder-limbs spring from an arch named the *pelvis*; this latter corresponding to the shoulder-girdle of the fore-limbs. The entire pelvis is V-shaped, the limbs of the letter being formed by the two *ilia* (figs. 40 and 43, *il*, *il*), or haunch-bones, which articulate in front or at the open extremity of the V, with the transverse processes of the sacrum, *s*. The bones forming each side of the pelvis are respectively named the *ilium*, *il*; *ischium*, *is*; and *pubis*, *p*. They unite to form the two lateral halves of the pelvis; these

halves uniting behind at the apex of the V-shaped pelvis, in the pubic *symphysis*. The point of union between the three pelvic bones of each side exists at the cup-shaped cavity or *acetabulum* (fig. 43, *ac*), in which the head of

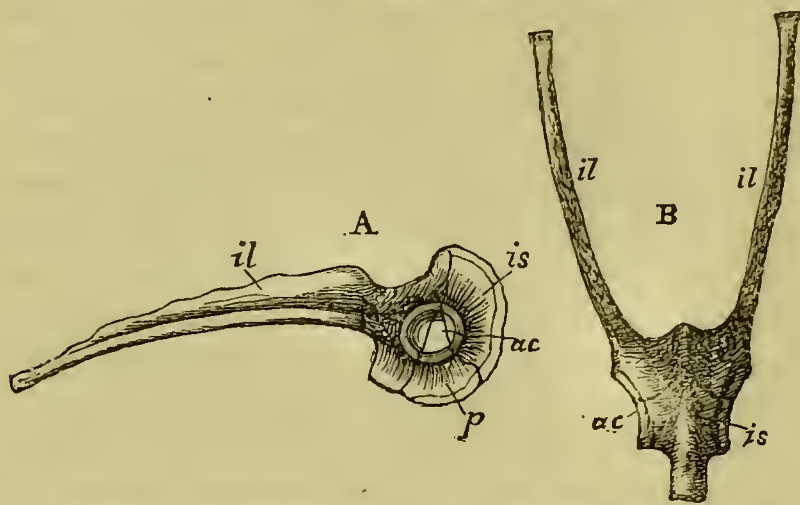

Fig. 43.—Pelvis of Frog: A, viewed from the side. B, from above; *il*, ilium; *is*, ischium; *p*, pubis; *ac*, acetabulum.

the thigh-bone rests. The pelvis, in consequence of the length of the ilia, can be flexed or bent upon the spine; and its mobility gives additional play to the hind-limbs in leaping. The parts of the leg correspond to those of the fore-limb. We find a thigh-bone or *femur* (fig. 40, *f*), and a leg-bone or *crus*, *t*, formed of two united bones, the *tibia* or *shin*, and the *fibula*. The ankle-bone or *tarsus* is formed firstly of two elongated bones—*astragalus*, *a*, and *calcaneum* or *os calcis*, *ca*—united at their extremities only, these bones giving to the leg a certain portion of its great relative length; and secondly, of two small cartilaginous pieces representing other bones of the ankle, better developed in higher animals. The length of the ankle constitutes a very characteristic feature of the frog's skeleton. The *metatarsus* or 'instep,' *mt*, is composed of five metatarsal bones, each of which supports a digit. The *hallux*, first or great toe, is innermost, and along with the second toe, consists of two phalanges. The third and fifth toes have three phalanges; whilst the fourth or longest toe is composed of four. Certain small cartilages

existing at the inner aspect of the tarsus are connected with the horny process formerly alluded to (par. 68), and known as the 'tarsal tubercle' or 'calcar.'

79. **HOW THE MOVEMENTS OF THE FROG ARE PERFORMED.**—The movements of the frog's body and those of the viscera are effected by means of specially developed muscles, which act under direct or indirect stimulation from the nervous system. The essential nature and structure of muscular tissue has already been referred to in the lesson on the *Anodon* or Fresh-water Mussel (see Chapter V., par. 41). In the frog, both varieties of muscle—striped and unstriped (fig. 19)—are found. The former variety is found in the *voluntary* muscles, or those of the body generally (fig. 45, *s*, *hy*); these muscles, exemplified by those of the limbs, trunk, and head, being under the command of the will. As in higher animals, however, the muscular fibres of the heart of the frog are also of striated kind; the heart being *involuntary* in its action, and not being under the command of the will. The unstriped muscles are sometimes named *hollow* muscles, and in the frog are seen in the muscular layers of the stomach, intestines, and other organs; these unstriped fibres being of involuntary nature. In the lobster, as we have noted, it is curious to find that all the muscles of the body, including those of the viscera, are composed of striped or striated fibres; those of the *Anodon* being entirely smooth or unstriped.

Muscular Contraction.—The contraction of muscles is produced, as we have noted, during life, under the stimuli or agency of the nerves which are distributed within them from the brain and spinal cord. After death, muscular contraction may also be excited by irritating the nerve in various ways, as by electricity; by contact with chemical substances, &c. Thus, when the sciatic nerve of a recently killed frog is exposed and placed in communication with electrical apparatus, the muscles of the calf may be made forcibly to contract; and the same result follows when the muscle is irritated directly and without operating upon it through the nerve. This experiment proves to us that muscular contractility, or the power in virtue of

which muscles shorten themselves, is a distinct property of muscular tissue, and that such a power exists independently of the nerves. The *myology* or disposition of the various muscles of the frog, is a subject which, from its mere extent, cannot be discussed in the present instance. We may simply note the great development of the limb-muscles, and especially of those belonging to the hind-legs ; and also the fact that each muscle consists of a fleshy central mass—the *belly* of the muscle—which is connected at each extremity to its bone or bones by a *tendon* or *sinew* composed of *white fibrous tissue.*

The Cellular Structure of the Frog's Tissues.—At the present stage of our inquiry, it may be instructive to note, that notwithstanding the diversity presented by the tissues of the adult frog, these membranes arise simply from the development of the primitive protoplasm of which the egg of the frog is composed. The process of specialisation thus proceeds to a much greater extent in the present case than in any previous example. And it may be further noted, that each tissue may be ultimately resolved or broken down into elementary parts or units ; these units being in each case simple *nucleated cells.* Thus bone, skin, muscle, nerve, and the other tissues of the frog exhibit a striking similarity in their ultimate composition. And it is not the least wonderful fact in the history of living organisms, that from a simple protoplasmic basis, the process of development should be capable of evolving structures of so many different kinds, but which nevertheless preserve an unmistakable identity of fundamental structure.

80. **THE DIGESTIVE SYSTEM.**—The *digestive system* of the frog exhibits an increased specialisation from that seen in the lobster or mussel. The mouth-cavity is very wide. Its roof is formed by the base of the skull, and in the central part of its floor, the body of the hyoid bone is situated. The hinder part of the mouth exhibits on each side two large openings, known as *Eustachian recesses,* leading to the internal ears ; and two other openings existing in the roof of the mouth are the hinder apertures (*posterior nares*) of the nostrils.

The *tongue* is fleshy, and divided in two at its free and posterior extremity; the frog's tongue, curiously enough, being fixed to the front of the lower jaw and floor of the mouth. When the animal protrudes its tongue, it is therefore the hinder extremity of the organ which is everted from the mouth; and by quickly throwing forwards this hinder portion, the frog captures insects with great dexterity. The tongue, when microscopically examined, is seen to be composed of muscles; whilst its surface bears little processes known as *papillæ*, these processes being invested with ciliated epithelium (fig. 14). The papillæ receive the terminations of those nerves (*glossopharyngeal*) specially exercising the function of taste, and therefore represent the essential parts of the tongue as an organ of taste.

The Frog's Teeth, &c.—The teeth of the frog are of small size, sharp-pointed, and recurved. They are borne by the margins of the upper jaw (premaxillæ and maxillæ), and on the vomers, in the front part of the roof of the mouth. No teeth exist in the lower jaw. The teeth are not implanted in sockets, but are united to the surfaces of the bones on which they are borne; and when lost or worn away, are replaced by new teeth, developed at the bases of their predecessors. The gullet opens at the posterior part of the mouth and throat, and leads into the stomach (fig. 44, *st*), which is of elongated shape, and lies to the left side of the body or 'abdominal' cavity. From the stomach the intestine is given off. The portion, *d*, which immediately originates from the stomach, is named the *small intestine*; its first part being named the *duodenum*. The *ileum*, *i*, or remainder of the small intestine, is convoluted or thrown

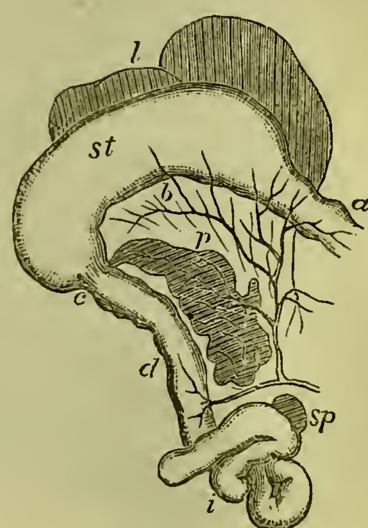

Fig. 44.—Viscera of Frog: *a*, cardiac or gullet extremity of stomach, *st*; *b*, mesentery; *c*, pyloric extremity of stomach; *d*, duodenum or first portion of intestine; *l*, liver; *p*, pancreas; *sp*, spleen; *i*, ileum.

into folds, which are attached to the walls of the body, and kept in place by a special fold of the *pleuro-peritoneal* membrane of the abdomen, termed the *mesentery*, *b*. This

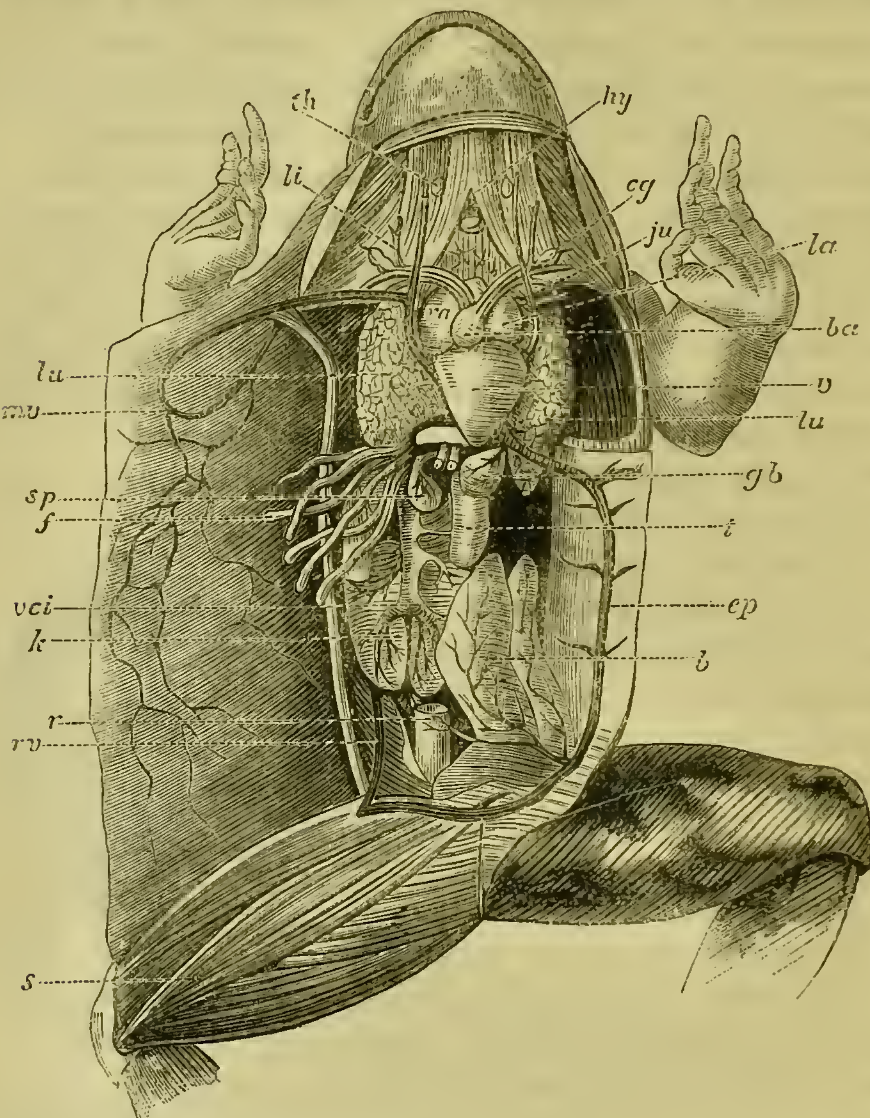

Fig. 45.—Viscera of Frog (Rolleston): *b*, urinary bladder; *ba*, *bulbus arteriosus*; *cg*, carotid gland; *f*, fat masses; *li*, lingual or tongue-artery; *lu*, *lu*, lungs; *ep*, epigastric vein; *ju*, left jugular vein; *gb*, gall-bladder; *sp*, spleen; *k*, kidneys; *ra*, right auricle; *la*, left auricle; and *v*, ventricle of heart; *th*, thyroid gland; *s*, sartorius; and *hy*, hyaglossi muscles; *rv*, renal vein; *r*, rectum; *vci*, inferior vena cava; *mv*, great veins passing to the skin; *t*, left testis.

latter structure is formed by the membrane (fig. 37, *b*, *b*) of each side of the abdomen uniting in the middle line. The last portion of the intestine is named the *colon* or *large*

intestine, from its greater width. Its terminal part, termed the *rectum* (fig. 45, *r*), opens into the cloaca. The lining membrane of the stomach exhibits a plicated or folded appearance, and the interior of the small intestine is similarly marked. The junction of the small and large intestine is indicated by the presence of a little valvular fold. The digestive system is lined by *epithelium*, which represents a layer or surface similar to that of the skin or epidermis, but folded inwards and modified to form the inner surface of the alimentary canal. This epithelial layer in certain situations becomes glandular, and, as in the stomach, forms the specialised glands, which secrete the *gastric juice*; this latter fluid being one of the chief agents concerned in the digestion of the food. The epithelial lining of the intestine is developed to form and invest numerous small processes or *villi*, which represent the openings of the *absorbent lymphatic* system, whereby the products of digestion are absorbed, and conveyed to be mixed with the blood-current or circulation.

Digestive Glands—Liver, Pancreas, &c.—The digestive system of the frog and of all vertebrata is thus seen to differ from that of the lobster, in that it turns away anteriorly from the nervous system, and is not encircled by any nerve-collar as in the latter animal; whilst it differs from that of the mussel and mollusca generally, in that the anus or termination exists at the posterior extremity of the body, and is not situated close to the mouth. The supplementary digestive glands in the frog consist firstly of a large two-lobed *liver* (fig. 44, *l*), secreting bile, together with a *gall-bladder*, in which bile may be stored up till required. The bile-duct from the liver opens into the duodenum. The minute structure of the frog's liver shews it to be composed of many-sided *hepatic* or biliary *cells*, each containing one or more nuclei. The bile is manufactured by the liver-cells from venous blood, brought to the organ by the *portal veins*. On this circumstance of part of the venous blood derived from the digestive system being sent to the liver for the manufacture of bile, a character distinctive of vertebrate animals has been founded. Certain elongated processes lying on

each side of the liver in the frog, have received the name of *fat* masses (fig. 45, *f*). The exact function of these bodies is hardly determined, but they probably subserve some secondary nutritive purpose. A *pancreas* or 'sweetbread' (fig. 44, *p*) is also found; this organ secreting the *pancreatic juice*, a fluid concerned, like the bile, in digestion, and closely resembling the saliva or fluid of the mouth. The frog's pancreas is a pale-coloured organ attached to the mesentery, *b*, near the posterior or pyloric extremity of the stomach, *c*. The *spleen* (figs. 44 and 45, *sp*), an organ more intimately concerned with the absorbent or blood-system than with the digestive organs, exists as a small gland of reddish colour attached to the mesentery, *b*, and situated near the junction of the duodenum and ileum.

81. **THE ABSORBENT OR LYMPHATIC SYSTEM—SPLEEN, &c.**—The food digested and elaborated in the digestive system was noted, in the mussel and all other invertebrata, to pass directly into the current of the blood, which it was destined to reinforce and augment. In the frog and all other vertebrates, a special system of vessels and spaces constituting the *lymphatic* or *absorbent* system, is provided for the *absorption* of the products of digestion. The lymphatic vessels, or *lacteals* as they are named, ramify in the wall of the intestine, and take up the matters which are strained through the villi (par. 80) of the intestine. The fluid contained in the lymphatic vessels is named *lymph*. It is a clear fluid, containing colourless, nucleated, amœba-like corpuscles or cells ; and consists of matters obtained by these vessels from all parts of the body, along with the matter derived from the digestion of food. It would appear that within these vessels, and also within the lymphatic glands, the lymphatic fluid—which closely resembles blood, save that it is colourless—undergoes some further elaboration, adapting it for renewing the blood, into the current of which it is sooner or later poured. The spleen (figs. 44 and 45, *sp*) is a gland connected with the lymphatic system, and probably serves to renew or to manufacture the blood-corpuscles. And three glands—the *thymus*, *thyroid* (fig. 45, *th*), and *adrenal* glands—may possibly possess

certain relations with the lymphatic vessels. The functions of these glands have not been determined even in higher vertebrata. The former two lie in the anterior part of the abdominal cavity of the frog; the latter being attached to the lower aspect of the kidneys.

THE LYMPH-HEARTS OF THE FROG.—In the frog, four pulsating organs, named *lymph-hearts,* are found developed on the lymphatic vessels; these structures serving to propel the lymph through the lymphatic vessels, and also to connect the latter vessels with the blood-circulation. Two of these lymph-hearts lie one on each side of the coccyx, and propel the contents of their vessels into the crural or leg veins. The other two hearts lie over the third vertebra, and send the lymph of the anterior lymphatics into the subclavian veins at the shoulder. The pleuro-peritoneal cavity of the frog (fig. 37, *e, e*), and other cavities of its body, act as large lymphatic sinuses or vessels, and convey lymph, which in due course is poured into the blood-current. We thus note, firstly, that the lymphatic system may be regarded as a connecting link between the digestive system and the circulation of the blood, whereby the latter fluid is supplied with matters adapted for its renewal; and secondly, that this system of vessels being found in Vertebrata alone, is to be regarded as forming a characteristic feature of these animals.

82. **THE FROG'S BLOOD AND BLOOD-VESSELS.**—The blood of the frog is *cold*—that is, is very little higher in temperature than the surrounding air. In mammals and birds, the blood is much warmer than the surrounding air, and hence these animals are named *warm-blooded.* When microscopically examined, the frog's blood is seen to consist of a colourless fluid, the *plasma,* in which float nucleated colourless corpuscles—derived from the lymph, and termed the *white corpuscles* of the blood—and also nucleated *red corpuscles* (fig. 46) of oval shape. The circulation of the blood in the frog can be well studied by the

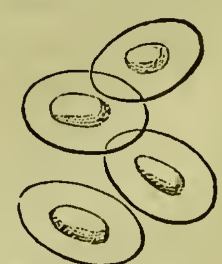

Fig. 46.—Blood Corpuscles of Frog (highly magnified).

microscopical observation of the thin web of the hind-feet. Such a view shews the smaller blood-vessels or capillaries, in which the arteries end, and from which the veins returning the impure blood to the heart take origin. The *arteries* of the frog possess thick walls, and contract, so as to propel the blood they contain, in virtue of the muscular layer in their walls. The veins are less muscular than the arteries. The circulation in the frog, and in all other vertebrates, is thus seen to be carried on entirely by means of closed blood-vessels. No ill-defined sinuses or spaces left between the organs and tissues, such as exist in invertebrates, participate in the circulation of the frog.

83. **THE FROG'S HEART.**—The *heart* of the frog consists, like that of Anodon, of two auricles and a ventricle; but it is a very different organ from the mussel's heart when regarded as to the manner in which its functions are performed. This three-chambered organ is contained within a heart-sac or *pericardium* (fig. 37, *p*), which lies on the front aspect of the liver. Within this sac—to which the heart is loosely attached—the heart may be seen pulsating in the recently decapitated frog; the two auricles contracting simultaneously, and the ventricle just afterwards. Even when removed from the body, the organ may continue to beat for a considerable time. The heart is a conical muscular organ; the lower or posterior ventricle (fig. 45, *v*), possessing thick walls of spongy texture; whilst the right, *ra*, and left auricle, *la* (together constituting the *atrium*), possess thinner walls. The auricles are completely separated internally by a thin septum or partition, and open each into the ventricle; the right auricle being larger than its neighbour. From the latter chamber a large thick-walled vessel—the *truncus arteriosus* or *aortic bulb*, *ba*—arises; this bulb dividing into two main trunks (*aortic arches*), each of which again divides into three main blood-vessels, known respectively as the *carotid artery* or trunk (fig. 47, 1, 1) *dorsal aorta*, 2, 2, and *pulmo-cutaneous* vessel, 3, 3. The aortic bulb contains three valves of crescentic shape, and at its lower portion an elongated vertical fold, constituting a movable septum or partition (fig. 47, *s*), exists

in the middle of the bulb. A large vessel named the *sinus venosus* receives the venous or impure blood brought by the two terminal veins, *vena cava inferior* and *superior* (figs. 45 and 47, *vc*); and in turn communicates with the *right* auricle, *ra*; whilst the *left* auricle, *la*, receives the *common pulmonary vein*, *pv*, which conveys pure blood thence from the lungs.

84. **CIRCULATION IN THE FROG.**—The *circulation* in the frog consists in the right and left auricles (fig. 47), through

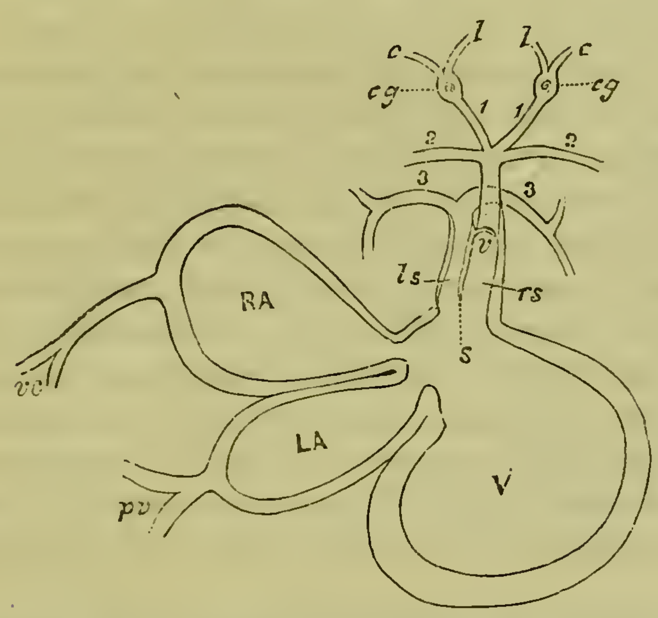

Fig. 47.—Diagrammatic (vertical) Section of Frog's Heart: RA, right auricle; LA, left auricle; V, ventricle; *vc*, venæ cavæ; *pv*, pulmonary vessels; *s*, movable partition dividing the bulbus arteriosus into a left, *ls*, and right side, *rs*; *v*, valve in right passage or side of arterial bulb; *cg*, carotid gland; *c*, carotid, and *l*, lingual arteries; 1, 1, the main carotid arteries; 2, 2, the two vessels which unite to form the dorsal aorta or artery; 3, 3, pulmo-cutaneous vessels leading to the lungs and skin.

their contraction, respectively throwing venous blood from the body and arterial or pure blood from the lungs, into the common ventricle, V. The ventricle next contracts in its turn, with the result of first sending the venous blood which has come from the right auricle into the aortic bulb. This venous blood passes on the left side, *ls*, of the movable partition, *s*, which shuts off the right passage; this impure blood being conveyed to the lungs and skin through the

pulmo-cutaneous vessels, 3, 3, for purification. Meanwhile, the remainder of the venous blood in the ventricle has become mixed with the arterial blood which the left auricle supplied. And as the contraction of the ventricle proceeds, this mixture of arterial and venous blood flows up the right side, *rs*, of the aortic bulb, and passes through the dorsal aortic trunks, 2, 2, to be distributed through the system and to nourish the body. The last result of the ventricle's contraction is to send the remainder of its blood—consisting of pure blood from the left auricle—through the carotid arteries, 1, 1, to supply the head.

Three notable points present themselves for remembrance in connection with the circulation in the frog. Thus (1), we note that a mixture of arterial and venous blood is sent through the system for the nourishment of the entire body except the head, which (2) is supplied with pure or arterial blood alone; and (3) that, whilst this systemic circulation of mixed or arterio-venous blood is characteristic of amphibians and reptiles, the higher vertebrata (mammals and birds) possess a complete circulation, or one in which venous and arterial blood are never mixed. The body in these highest animals is supplied with pure or arterial blood only, whilst the venous blood is conveyed to the lungs for purification.

85. **EXCRETION IN THE FROG—LUNGS, SKIN, AND KIDNEYS.**—The *excretory organs* of the adult frog consist of the *lungs*, *skin*, and *kidneys*. The former (fig. 45, *lu*, *lu*) are two elastic sacs, of oval shape, bounded by thin walls, and having their interior divided into numerous little sacs or air-cells. On the walls of these cells, the pulmonary or lung blood-vessels branch out in a fine capillary network, and blood circulating in these vessels receives oxygen from the atmospheric air inhaled by the frog; whilst carbonic acid, heat, and watery vapour are exhaled. The lungs lie on the dorsal aspect of the abdominal cavity, one on each side of the gullet. Air is admitted to the lungs by a slit or *glottis*, existing in the floor of the *pharynx* or back part of the mouth. This opening may be seen when the frog's mouth is widely opened. From the glottis, which is bounded

by two (*arytenoid*) cartilages, a short, stunted, cartilaginous tube, representing the organ of voice (*larynx*) and windpipe (*trachea*) of other animals, leads to the lungs. Air in higher vertebrates is inhaled into the lungs by the movements of the chest; but as the frog has no ribs to form a chest, breathing is carried on in this instance by a process of *swallowing* air, rather than by regularly inspiring it. Thus the Frog, in breathing, first fills the mouth through the nostrils. The posterior nostrils opening into the mouth are next closed by the tongue being applied to these orifices; whilst the hyoid bone and floor of the mouth are elevated. The opening of the gullet being thus also closed, the air is driven down the only aperture left open—namely, that of the glottis—into the lungs. Expiration in the frog, or the reverse action of inhaling air, is accomplished probably by the elasticity of the lungs, and by the contraction of the surrounding muscles. The closure of the frog's mouth is thus absolutely necessary for the performance of respiration: and to forcibly keep the mouth of the animal open for any great length of time, is a procedure equivalent to suffocating it. The organ of voice in the frog consists of two sacs lying within the glottis; the edges of these sacs forming the *vocal cords*, the vibration of which produces the 'croak' or voice of the animal.

FUNCTIONS OF THE FROG'S SKIN AND KIDNEYS.—The skin of the frog, as already remarked, powerfully aids in the process of excretion, by giving off large quantities of watery vapour, secreted from the blood by means of its glands. The *cutaneous* or skin veins (fig. 45, *mv*) are very large and numerous, and thus bear a definite relation to the functions of the membrane. The kidneys (fig. 45, *k*) serving to excrete nitrogenous waste matters (chiefly *urea*, *uric acid*, and *water*), consist of two organs of elongated shape, lying in the abdominal cavity. Each kidney exhibits a tubular structure, the tubes having a lining of epithelial cells, and being adapted for straining off the waste products above mentioned from the blood brought to the kidneys by the veins. The *ureters* or ducts of the kidneys open each by a slit into the hinder wall of the *cloaca*. The *urinary*

bladder is represented by a double sac (fig. 45, *b*), which also opens into the front portion of the cloaca below the rectum. The kidneys of the frog, in reality, consist of certain organs developed in the embryo or immature form, and known as the *Wolffian bodies.* The kidneys of higher animals are developed separately from the Wolffian bodies, and replace the latter organs. The urinary bladder in the frog does not receive the urine, and merely represents part of a sac found in the embryo, and named the *allantois.*

86. **THE FROG'S NERVOUS SYSTEM.**—The *nervous system* of the frog is not only partitioned off from the general body-cavity as we have seen, but is also much more highly specialised than that of any invertebrate forms. We thus find a *brain* and *spinal cord* specially developed to act as nerve-centres ; the nerves serving as before to convey impressions to or from these centres. The morphology of the nerve-centres in the frog is of too complicated a nature to be thoroughly understood without a previous acquaintance with the anatomy and physiology of the nerve-centres of higher animals. A very few points only, by way of general description of the nervous axis of the frog, must therefore suffice. Little or no comparison can be made between the nerve-centres of a vertebrate and invertebrate animal. As we have already noted (par. 70), the dorsal or neural tube of the former, with its contained brain and spinal cord—constituting the *cerebro-spinal* nervous system—is entirely unrepresented in invertebrata. If the nervous system of the latter is homologous with any part of the nerve-axis of vertebrates, it is most probably with the second system of nerves, found within the body-cavities of vertebrata, and known as the *sympathetic system.*

87. **THE FROG'S BRAIN.**—The cerebro-spinal axis in the frog constitutes the chief and representative nervous system of the body. It consists of the *encephalon* or *brain* and of the *myelon* or spinal cord ; the latter being in fact a continuation backwards of the brain. The latter consists of the six chief regions which are traceable in the brain of man himself. Thus, in front (fig. 48), we find the *olfactory lobe*, *ol*, giving origin to the *olfactory nerves*,

b, or those exercising the sense of smell. Next in order, as we proceed backwards, we find the *cerebral hemispheres*, *c*, representing the great mass of the brain (*cerebrum* or 'true brain') in man. Each hemisphere contains a small cavity—the *lateral ventricle*. Succeeding the cerebral hemispheres, we find a portion named the *thalamencephalon*, or optic thalamus, *t*, which contains a cavity, the *third ventricle* of the brain, and which has in close connection with it the *pineal gland* and *pituitary body*, *e*. The *optic lobes*, *op*, giving origin to the *optic nerves*, *d*, or those exercising the sense of sight, come next in order; the small *cerebellum* or 'lesser brain,' *cb*, lying behind the optic lobes. The last or hinder segment of the brain is the *medulla oblongata*, *m*, in which the spinal cord ends above. Within this latter portion, a cavity known as the *fourth ventricle*, *v*, is situated. Ten pairs of *cranial nerves* are given off from the brain; these being the (1) *olfactory*, *b*; (2) *optic*, *d*; (3 and 4) *motores oculorum* and *pathetici*, or those moving the muscles of the eye; (5) *trigeminal*, supplying the skin of the head and jaw-muscles; (6) *abducentes*, supplying certain of the eye-muscles; (7) *facial* nerves; (8) *auditory*, or nerves of hearing, *au*; (9) *glossopharyngeal*, or nerves of taste and the muscles of pharynx; (10) *pneumogastric* or *vagi*, supplying the larynx, stomach, lungs, heart, &c.

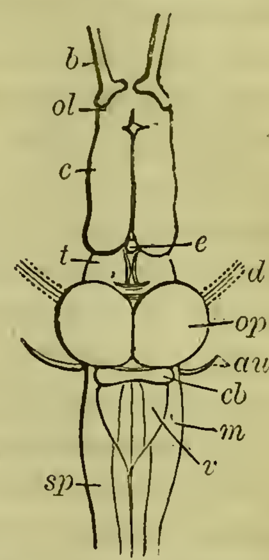

Fig. 48.—Brain of Frog: *b*, olfactory nerves; *ol*, olfactory lobes; *c*, cerebral lobes; *e*, pineal gland; *t*, optic thalamus; *d*, origin of optic nerves; *op*, optic lobes; *au*, auditory nerves; *cb*, cerebellum; *m*, medulla oblongata; *v*, position of fourth ventricle; *sp*, commencement of spinal cord.

THE FROG'S SPINAL CORD.—The *spinal cord*, *sp*, is continued from the brain backwards to the seventh vertebra, from which point it extends to the coccyx as a slender filament. Two grooves (dorsal and ventral) nearly divide the spinal cord into two halves along its length. The cord contains a small central canal, which ends in the fourth

ventricle, *v*, of the brain. Ten pairs of *spinal nerves* are given off from the spinal cord. Each nerve originates by two (*dorsal* and *ventral*) *roots*. These roots indicate the presence of two distinct sets of fibres, known as *sensory* and *motor*, in the nerves formed by their union. The manner in which these fibres act to co-ordinate the ordinary movements and actions of the animal, will be found explained in *Animal Physiology* (Chambers's Elementary Science Manuals), page 119, where also the nature and structure of the organs of sense are duly noted. The latter in the frog consist of eyes, ears, a tongue exercising the sense of taste, nostrils provided with olfactory nerves, and the skin and its papillæ serving as the organ of touch.

The Sympathetic Nerves.—The *sympathetic system* of nerves in the frog consists of ten *ganglia*, or masses of nervous matter, united by commissural cords, lying on the front of the spine, and within the body-cavity. It must be noted, that the sympathetic system is not inclosed within any special tube, or separated from the other organs of the body, as is the case with the brain and spinal cord. The sympathetic nerves are connected by branches with the spinal nerves; and their filaments are distributed chiefly to the blood-vessels, to the viscera of the body generally, and to parts which are involuntary in their action or without the command of the will.

88. **Structure of Nerves.**—The nerves of the frog, when microscopically examined, are seen to be composed of *nerve-fibres*; each fibre exhibiting a double outline, and being composed of an outer or *primitive sheath*, within which a second or *medullary sheath* is contained; whilst the central portion of the fibre is composed of a uniform substance known as the *axis cylinder*. The nerve-masses or *ganglia*, which exist in connection with the nerves, and which are well seen in the sympathetic system for example, consist of large nucleated cells containing granular contents; whilst in the spinal cord, nerve-cells of similar kind, but which give off branches, are found.

89. **REPRODUCTION AND DEVELOPMENT OF THE FROG.**—The *reproduction and development* of the frog, like that

of every other vertebrate, is carried on solely by means of fertilised ova or eggs ; and as in all vertebrates, the sexes are distinct. We thus note in vertebrata an absence of the asexual processes of reproduction (par. 16) common in many groups of invertebrate animals. The *testes* (fig. 45, *t*) lie in front of the kidneys. They are bodies of yellowish colour ; and the duct or outlet of each enters the kidney, the secretion of the testes being thus emitted through the ureters or ducts of the kidneys. The spermatozoöids of the common frog are mobile bodies, resembling simple filaments, without any distinct head. The *ovaries* at the breeding-season appear as large organs exhibiting a folded appearance, and divided internally into compartments containing the *ovisacs.* The latter in turn contain the *ova* or eggs, which pass from each ovary through the *oviduct*, a long tube opening on the hinder aspect of the *cloaca.* The eggs may be found in ponds and streams in the early spring; each consisting of a structureless outer envelope, or *vitelline membrane*, containing a *vitellus* or *yolk*, coloured partly pale and partly dark. The yolk contains the essential part of the egg—the *germinal vesicle* and *germinal spots.* The eggs are deposited singly, and are duly fertilised by contact with the spermatozoöids, which appear to enter the egg and to penetrate its substance. In the water, the outer membrane of each egg swells through the imbibition of that fluid, and the eggs thus become aggregated together, and present the appearance of great masses of jelly-like substance, amidst which the separate yolks may be seen as so many dark particles.

90. **WHAT IS OBSERVED IN THE DEVELOPMENT OF THE FROG'S EGG.**—Development of the frog's egg depends greatly on the surrounding temperature, and is ushered in by the *segmentation of the yolk* (fig. 49, *a* to *h*), this process terminating in the formation of the 'mulberry-stage,' or *morula*, already alluded to in connection with the development of Hydra. Segmentation of the yolk begins usually about three hours after the egg has been impregnated. The changes sketched in commencing our study of the frog next ensue; the blastoderm and notochord being formed, and the plan

of the vertebrate body with its dorsal and ventral tubes being outlined. The layers of the blastoderm are meanwhile being developed to form the various parts and surfaces of the young animal; and finally the embryo, whilst still within

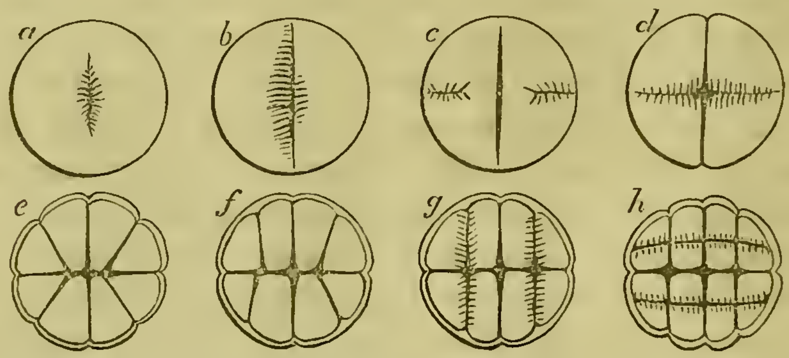

Fig. 49.—Development of Frog's Egg: *a* to *h*, successive stages in segmentation of the frog's egg from the beginning of the process *a*, to the mulberry-stage, *h*.

the egg, presents the appearance of a little fish-like and limbless creature, popularly known as a 'Tadpole.' This little larva possesses two little discs or suckers (fig. 50, *s*, *s*), situated behind the mouth on the lower aspect of the head; these structures enabling it to attach itself to fixed objects. Six clefts (fig. 50, D, *cl*, 1 to 6), named *branchial* or *visceral clefts*, opening into the throat, appear on each side of the neck; these slits being separated by partitions, the visceral or branchial *arches*. The presence of these clefts and arches in the early life of all vertebrates, naturally constitutes a distinctive feature of these animals. In fishes and certain amphibians only, are these clefts represented in adult life.

Anatomy of the Tadpole.—The eggs of the frog are 'hatched' towards the end of April, and the contained tadpoles escape into the surrounding water. Two tufts, the *external branchiæ* or *gills* (fig. 50, A, B, *g*, *g*), next appear to be developed from the branchial arches; each gill being a plume-like structure, containing minute blood-vessels, in which the blood of the tadpole is exposed to the action of the surrounding oxygen. Water inhaled by the mouth escapes by the branchial clefts. The creature now possesses a relatively large head, and a fish-like tail bordered with a soft fin, not supported, however, by any rays, such as are

found in fishes. It lives upon vegetable matters, which it is enabled to masticate by means of the horny sheaths (fig. 50, B, *j*) with which the jaws are provided, and a long

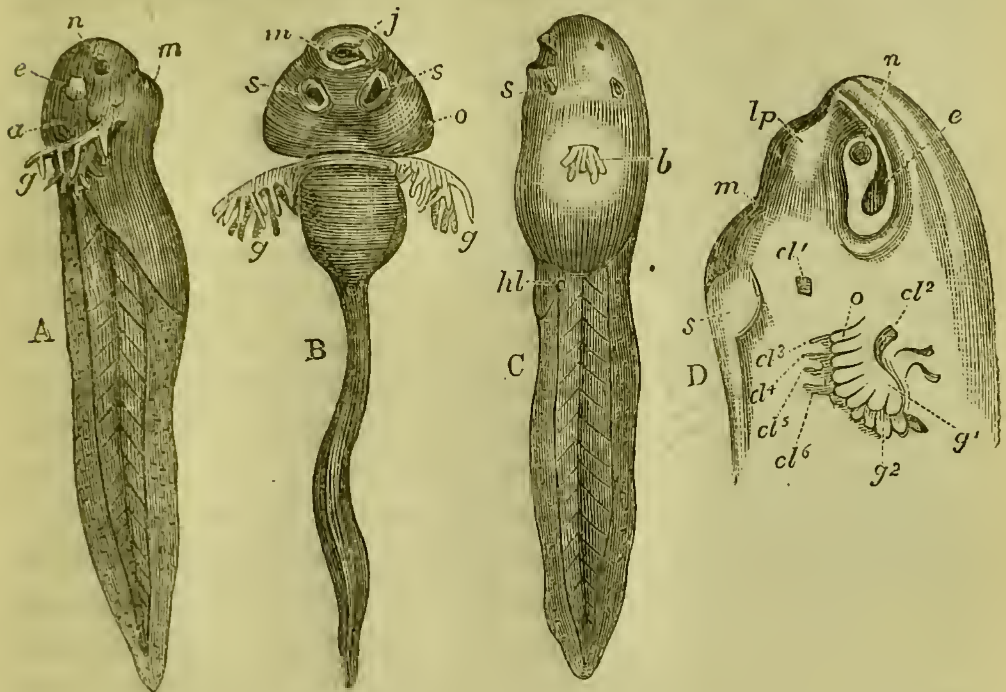

Fig. 50.—Anatomy of Tadpole: A, side view of tadpole, shewing outer branchiæ or gills, *g*; mouth, *m*; nasal sacs, *n*; eye, *e*; ear, *a*. B, the same viewed from below; *s*, *s*, suckers; *o*, operculum; *j*, horny jaws. C, more advanced tadpole, shewing the growth of the operculum, so as to inclose the gills save at the opening, *b*, on the left side; *hl*, rudiment of hind-limbs; *s*, sucker. D, head of young tadpole (magnified); g^1, g^2, external gills; *lp*, upper lip; cl^1 to cl^6, visceral clefts. (Other references as in figs. A, B, and C.)

intestine is seen to exist coiled up in its interior. The tail is highly muscular, and serves as a swimming-organ; and thus in its earliest stages, the young frog is essentially fish-like both in appearance and habits.

The next changes of importance that ensue, consist in the development of an *operculum* or gill-cover (fig. 50, *o*), which covers the branchial clefts, incloses the external gills, and which, on the left side of the body, leaves for a little time a single gill-aperture (fig. 50, C, *b*). The outer gills, however, soon disappear, and in its next stage the tadpole breathes like a fish by *internal* gills, which are developed on the inner side of the four branchial arches. The *limbs*

next appear as little buds which sprout from the sides of the body; the hind-limbs, *hl*, being first visible in the frog, since the front-limbs are for a time concealed by the operculum. As the legs increase in size, the tail decreases; and lungs are meanwhile being developed as little sacs, which sprout from the lower side of the gullet. For a time the tadpole breathes both by its internal gills and lungs, and resembles at this stage certain of its amphibian neighbours, such as the *Proteus*, the *Axolotl*, &c. Finally, the gills disappear; the branchial apertures become wholly closed; the nostrils, at first mere sacs or pouches, communicate internally with the mouth and throat; and as the tadpole leaves the water to breathe henceforward by lungs alone, the change from an aquatic to a terrestrial existence may be said to be completed.

METAMORPHOSIS.—The long intestine of the vegetable-feeding tadpole, at the same time, becomes the shorter intestine of the insect-eating frog; and important changes are also carried out in the heart and circulation as development proceeds. Thus the heart of the tadpole resembles that of a fish, and consists of a single auricle and a ventricle before the appearance of the lungs. The single auricle then becomes divided into two as in the adult; and further changes of complicated nature ensue on the disappearance of the internal gills, and the installation of the lungs as the sole breathing organs of the adult frog. The series of developmental changes thus chronicled, receives the name of *metamorphosis*; and analogous phenomena are seen, as is well known, in the development of many insects and other invertebrata.

91. **THE FROG'S PLACE AMONGST VERTEBRATE ANIMALS.**—The frog is known to be an *Amphibian* vertebrate, firstly, because it breathes in early life by means of gills, and afterwards by lungs. The remaining characters distinctive of its class, are found in the presence of *two* occipital condyles, by means of which the skull articulates with the spine; in the possession of true limbs, and in the absence of fin-rays, such as exist in fishes; in the development of a three-chambered heart; in the nostrils opening

posteriorly into the mouth; in the absence of an exoskeleton; and in the possession of a *cloaca*, into which the digestive, reproductive, and urinary systems open.

92. **SUMMARY OF THE CHARACTERS OF VERTEBRATA.**—The various vertebrate characters of the frog have been duly noted at various stages in our study of its morphology and physiology. It differs from the lobster, mussel, hydra, amœba, and all other invertebrates, in that it possesses (1) a *notochord* in early life; (2) a *body* consisting of *two cavities*, the upper of which contains the nervous system; (3) *branchial arches* or *clefts* in its young state; (4) *limbs* turned away from the nervous axis, and supported by an internal skeleton; (5) jaws, which are parts of the head, and not merely modified limbs; (6) an *alimentary canal* which does not pierce the nervous system anteriorly; (7) a *portal system* of veins carrying blood to the liver; and (8) *absorbent* or *lymphatic* vessels, which elaborate and convey the products of digestion to augment and renew the blood circulation.

QUESTIONS.

Section 1. Of what objects does the science of Biology treat?

3. Describe the external features of an *Amœba.*

4. What is protoplasm? Describe its chemical composition and physical properties. Why is this substance named the 'physical basis of life?'

5. Describe the structure of an amœba. What are pseudopodia, contractile vesicles, and food-vacuoles? Why is the amœba placed in the class Rhizopoda?

6. How does the amœba receive and digest food? What simple plan may be adopted to shew how food is ingested? What is the 'villous region' in amœba?

7. What features in amœba suggest that a circulation of its fluids takes place? How may we conceive the amœba to possess sensibility in the absence of a nervous system? Name some plants which are sensitive.

8. What is the reproductive function? Describe the processes of reproduction which occur in amœba.

9. Name the different species of amœbæ. Which animals are most nearly allied to amœba?

10. What are the essential points to be noted in the study of living beings?

11. What are the relations of protoplasm to life and vital action?

12. Shew how ordinary modes of distinguishing between animals and plants fail. What are the most reliable distinctive points between animals and plants? Shew how the two groups become related through their food.

How do we scientifically distinguish between different animals?

13. What is Hydra, and where is it found? Describe the size and general appearance of hydra. How do we become aware that hydra is sensitive?

14. Describe the microscopic structure of the hydra's body. What are ordinary cells? Describe a 'thread-cell.' What is the general plan of the hydra's body?

15. How does the hydra feed itself, and how is prey captured? Note the functions of thread-cells. How is food digested, and how is circulation performed? How does hydra feel in the absence of nerves?

16. What is the difference between sexual and asexual reproduction? Describe the process of *fission* and *gemmation* as these processes are exhibited in the hydra; and state why gemmation in hydra is named 'discontinuous.'

17. Describe the reproductive organs of hydra. What are the essential parts of an egg or ovum; and with what structure is the egg identical? Describe the stages observed in the development of hydra. Name the various species of these animals.

18. To what group of animals does the hydra belong? Give the characters of this group as illustrated by the hydra. What is meant by 'morphological type?'

19. Compare the hydra with amœba. Illustrate the principle known as the 'physiological division of labour.' Give examples of 'retrogression' in animal development. Define true or sexual reproduction, and explain the terms 'monœcious' and 'diœcious.'

20. What are the proofs that hydra is an animal?

21. What are Zoophytes? Describe their relations to hydra. Name the two classes of Cœlenterata. Note the naked-eye and microscopic appearances of a 'sea-fir.'

22. Through what process could we suppose a hydra to become

converted into a zoophyte-form? Explain the terms *hydrosoma, polypary, hydrorhiza, proximal, distal, polypite,* and *hydrotheca.*

23. How is a zoophyte nourished?

24, 25. Explain the meaning of the terms *trophosome* and *gonosome.* What comparison is admissible between a zoophyte and a tree? How is true reproduction performed in the sea-firs? What phases of zoophyte-reproduction are of more complicated kind, and what are the relations of the Medusa-like bodies to the zoophyte? Describe the structure of a Medusa-bud; and note its life-history.

26, 27. Describe the nature of 'compound' animals as illustrated by the zoophyte. What is the true zoological 'individual?' Shew whether the zoophyte is an individual or a 'zoöid,' and explain the meaning of the latter term.

28. What is meant by the term 'alternation of generations?' Explain why the phrase is now regarded as inapplicable.

29. Describe the external appearance of a Sea-anemone.

30. Give a description of the anemone's structure. What is peculiar in the structure of the anemone's stomach-sac? What are mesenteries, and into what series may the mesenteries be divided? What is the law of growth of the mesenteries?

31. Describe the tentacles of the anemone. What function has been attributed to the pigment-spots?

32. Describe the microscopic structure of the anemone's tissues. Which layer develops muscular tissue? Note the structure of the stomach-sac, with special reference to its muscular development. What are *cilia?* In what situations in the anemone and in other animals are they found? Note the size and function of these filaments.

33. What are *craspeda* and *acontia?* Describe the reproductive organs of the anemone. What are *cinclides?*

34. Describe the nutrition of the anemones. What is the 'chylaqueous fluid?' How is innervation performed in the anemone? In what allies of the anemone does a distinct nervous system exist?

35. What processes of reproduction are exemplified in the sea-anemone? Describe its development.

36. What is 'commensalism?'

37. To what class of Cœlenterata does the anemone belong; and what are the differences between this class and that to which the hydra belongs? What are the relations of the coral-polypes to the sea-anemones?

38. Name the various kinds of mussels. To what group and

class of the animal world do the mussels belong? Describe the mussel's shell; and explain the terms *dorsal*, *ventral*, *posterior*, and *anterior* borders of the shell. How may the surfaces of the shell be determined? Illustrate the terms *inequilateral* and *equivalve* by the mussel's shell.

39. What points are observed in a living mussel?

40. Describe the minute structure of the shell? How is the shell formed? How do we open the shell of the mussel? What are pearls? What is meant by the *secretion* of the shell? Describe the means whereby the shell is opened and shut.

41, 42. Enumerate the chief muscles of anodon. What are the impressions seen on the internal surface of the shell? Describe the structure and varieties of muscular tissue. How do muscles act? What is the 'foot?' Mention the chief muscles of the foot. Give a sketch of the general plan of structure of the mussel's body.

43. What is the mantle? Explain how the mantle forms the 'pallial' and 'anal chambers' and the 'siphons' of the mussel.

44. Describe the course of the digestive system and the digestive glands of the mussel. What are 'labial palpi?' What is the 'crystalline style?'

45. How are nutritive matters absorbed from the digestive system of the mussel; and what are the characters of the mussel's blood? Describe the heart of anodon.

What is the 'organ of Bojanus?' Describe its structure and functions.

46. How does the mussel breathe? What is the essential nature of the breathing-function? Describe the structure of a gill. How is water admitted to and expelled from the gills of anodon? Describe the course of the blood-circulation in the mussel. What is meant by the process of 'excretion?' State how this process is performed in anodon. Why is the heart of anodon termed 'systemic?'

47. Of what parts does the nervous system of anodon consist? Describe the minute structure of the nerves. What senses are represented in anodon? Describe the organ of hearing.

48. How does the nervous system act? What relation do the nervous acts of the mussel bear to those of higher animals?

49. What reproductive processes are represented in anodon? Describe the reproductive organs and development of the mussel. What is *Glochidium?*

50. Why may the mussel be regarded as a higher animal than

the sea-anemone? In what respects does the mussel agree with other Lamellibranchiates? Name the other groups of animals which are included in the sub-kingdom Mollusca.

51. What is the relationship between the lobster and cray-fish? Why is the lobster said to be 'bilaterally symmetrical?' In what sub-kingdom and class is the lobster contained? Give the derivation of the name of its class. What is the nature and structure of the shell?

52. How many joints are included in the body of the lobster? Give a general description of the chief regions of its body.

53. Describe the abdominal segments in order. What relation does the telson bear to the other segments?

54. What is the cephalothorax? Describe the appendages of the thorax proceeding from behind forwards, and shew how the appendages in reality conform to the type seen in the joints of the abdominal segments. What is the 'epipodite?' How many segments compose the head? What is peculiar in the structure of the second pair of maxillæ? Describe the mandibles. What are the appendages of the three foremost segments of the head? Define the 'branchiostegites.'

55. Define Homology, and illustrate your answer by a reference to the lobster's body. How are the deductions of homology proved? What is 'ecdysis?'

56. In what region of the lobster's body are the digestive, nervous, and blood systems respectively situated? Describe the relations existing between the nervous system and gullet. Describe the lobster's stomach. Where does the intestine terminate? In what region is the liver situated? Describe its minute structure.

57. Where does the lobster's heart lie, and how can it be seen in a pulsating condition? Describe the form and openings of the heart. What are 'sinuses?'

58. Describe the structure of a gill. What structures form the gill-chamber of the lobster? How is respiration performed in the lobster? What are the functions of the 'scaphognathites,' and what structures do they replace? What are the 'brancho-cardiac canals?' Describe the course of the circulation in the lobster, and compare the heart and circulation with that of the mussel.

59. What are the 'green glands?' where are they situated? and what is their probable function?

60. Describe the minute structure of the lobster's muscles.

61. What is a ganglion? What does development teach concerning the disposition of the lobster's nervous system? Describe

the nervous system of the adult lobster. Describe the eyes. Where are the ears situated? Note the structure of the latter organs. What is the microscopic structure of the lobster's nervous system?

62. What are the distinguishing features of the male and female lobsters? Describe the reproductive organs of each sex.

63. What is known as the 'zoea-form' of the lobster, and how does the embryo differ from the adult?

64. What are the chief differences between the lobster and crayfish.

65. Shew how the lobster illustrates the characters of its sub-kingdom.

66. Give examples of animals belonging to the classes *Myriapoda*, *Insecta*, and *Arachnida*. In what respects does the class *Crustacea* differ from these groups?

How are the affinities of animals to be studied?

67. What characters lead us to name the frog a *vertebrate* animal?

68. Describe carefully the external appearance of a frog. What is meant by an endoskeleton? What is the 'tympanic membrane?'

69, 70. What acts may a living frog be ordinarily observed to perform? Give a sketch of the general plan on which the frog's body is constructed. Compare—through the answer to the preceding question—the general plan of structure of the frog with that of the lobster.

71. Which characters of vertebrates may be traced at an early stage of their development? Specially describe the notochord in your answer.

72. Note the characters of vertebrate limbs, and compare them with those of Invertebrata.

73. Describe the structure of the frog's skin. What skin-structures are specially associated with its excretory work? How does the skin grow? Shew how the skin in the frog becomes intimately associated with respiration.

74. Amongst which structures should the teeth of the frog be properly included? What is the general disposition of the frog's skeleton? Sketch the general manner of its development. How and from what structures is bone developed?

75. What is a 'vertebra?' How many vertebræ exist in the frog? Describe the composition of a vertebra, and note the structure of the spine. What are the uses of the spine? Describe the

composition of the frog's pelvis. What is the 'coccyx?' How is this bone formed? Are ribs developed in the frog?

76. Give a general description of the frog's skull. How is the lower jaw articulated to the skull? Where is the 'hyoid bone' situated?

77. Describe the shoulder-girdle and fore-limb of the frog. What is meant by 'pronation' and 'supination?'

78. Describe the pelvic girdle and hind-limb.

79. Note the varieties of muscular tissue found in the frog; and compare the muscles of the latter with those of the lobster and mussel. How is muscular contraction exerted? Why may the frog be properly described as a 'cellular organism?'

80. What structures and openings are seen in the mouth of the frog? Describe the teeth, and course of the digestive system. What is the mesentery? What membrane lines the digestive system? Explain the meaning of the names *epithelium*, *villi*, *hepatic cells*, and *portal veins*.

Describe the frog's liver. How and from what is *bile* manufactured? What are the 'fat masses?' What are the 'pancreas' and 'spleen?'

81. Describe the functions of the 'absorbent system.' What are 'lymphatics?' Note the situations of the *thyroid*, *thymus*, and *adrenal* glands.

What are lymph-hearts, and where do these structures exist in the frog?

82. Describe the microscopic appearance of the frog's blood. What is meant by 'nucleated' corpuscles? What are 'arteries' and 'veins?'

83. How many chambers exist in the frog's heart, and where is the organ situated? Describe its internal structure, and note the chief blood-vessels which enter and leave it.

Note the course of the blood-circulation through the heart. What are the characters of the blood which is circulated generally through the frog's body? Shew how the mechanism of the heart ensures the circulation of pure blood through the head.

85. What are the excretory organs of the frog? Describe the position and structure of the lungs. Shew how breathing is performed in the absence of ribs. What are the functions of the kidneys? Describe the structure of these organs. What is the 'cloaca?' Compare the work of the lungs, skin, and kidneys.

86. In what respects does the nervous system of the frog differ

from that of the lobster or mussel? What constitutes the 'cerebro-spinal' nervous system?

87. Describe the frog's brain. What nerves arise from the brain? Describe generally the spinal cord and the chief nerves which originate therefrom. What is the sympathetic system, and what are its functions?

88. Describe the minute structure of the frog's nerves.

89. Note the structure of the frog's reproductive organs. Describe the structure of the egg, and the changes which follow impregnation.

90. Describe briefly the development of the frog's egg. Enumerate the chief points in the anatomy of the 'tadpole.' Define the names *branchiæ* and *operculum*. To what animals does the young frog at different stages of its development bear a resemblance? What is meant by 'metamorphosis,' and in what animals does this process occur?

91. To what class of vertebrates does the frog belong? What are the characters which distinguish this class?

92. Give a summary of the principal characters of Vertebrata, and note those points in which the lobster and mussel specially differ from the frog.

THE END.

Edinburgh:
Printed by W. & R. Chambers.